DENTAL

RADIOLOGY

ERRATA Applying to figure 1.

The FINSEN RAYS bracket should only extend dow: and include Ultra-Violet not Bi-Ultra-Violet and Trio-U. Violet.

The CHEMICALLY ACTIVE RAYS bracket should c extend up to and include Red, not Ultra-Red.

DENTAL

RADIOLOGY

BY

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PUBLISHED BY

SWENARTON STATIONERY COMPANY

PRINTERS AND PUBLISHERS

121 EAST 27TH STREET

NEW YORK, N. Y.

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PREFACE

The author desires to express his sincere thanks for suggestions, information or the use of cuts from the following:

Mr. Irwin Howell, of the General Electric Co.

The American X Ray Equipment Co.

The Wappler Electric Mfg. Co.

MacAlaster & Wiggin Co.

Waite & Bartlett Co.

Since this book is written primarily as a text book for the undergraduate dental student, to be used in the laboratory, and while attending clinical lectures, blank pages have been inserted between the chapters to facilitate the student in the taking of additional notes, and to insure their proper preservation associated with the subject to which they belong.

It is earnestly hoped by the author that all students will take advantage of these note pages while attending lectures.

Any suggestions or criticisms, favorable or otherwise, will be welcomed by the author.

Francis Le Roy Satterlee, Jr.

148 East 18th Street
New York City

August 1, 1913

INTRODUCTION

What Radiology Means to You — A Plain Talk with the Undergraduate

What real value is Radiology to the dentist? That is a question that is being answered every day by one's own practice, although sometimes the practitioner ignores or does not understand the answer. Some of you are willing to work along in the same old rut and not attempt to utilize the advantages of the recent discoveries in modern science, until you become back numbers; and then take them up only because you are afraid to be elected in the "fogy" club if you do not. Others rush ahead heedlessly into fields unknown, without blazing any trail, with the result that suddenly they realize that they are in a wilderness and hopelessly lost. Which is the greater of these two evils is hard to say, but I think, of the two, the last man has the best chance to succeed, since some friend may happen to come along at the moment he is beating around looking for the trail and "lead him to it." But the really successful man is he who goes through life with his eyes open, his ears open, and his mouth shut; his hands out ready to grasp anything new that comes along; to inspect it, study it, and, if it appears to be at all useful to him, to store it away in his brain with a tag "keep forward" on it; ever ready to take it out and refer or add to it, till, at length, he has developed a subject full of interest and usefulness, that has been matured and ripened into an established and working rule or adjunct of his profession.

This is the man who to-day will be able to answer the question I first put to you, and he will tell you many things

you little dreamed of. He will tell you first that the subject of Dental Radiology embraces quite a field, the one part of which has been well cultivated, while the other part is more or less barren. The cultivated part he will tell you is that part of the subject which deals with the X Ray as a diagnostic agent; the uncultivated part being the use of the X Ray as a therapeutic agent. If he is truthful, he will probably add that he does not mean to disparage the latter subject, but only wishes to profess unfamiliarity with it, although looking forward to future developments. You will probably ask this sensible man, if you are really seeking enlightenment, what he has found in the X Ray to be of any benefit to him and how? He may look at you with a supreme smile of pity and tell you to open your eyes and test it yourself, or he may try to explain some of the uses of the ray to you. If he is very generous and willing to help you along, and has, besides some leisure time, he will take you to his office and show you some of the recent cases that he used the X Ray on, and with what results. You will take out your note book and will make notes something like this:

"X Rays used with good success in cases of impacted teeth, non-erupted and supernumerary teeth, regulating cases. Fractures of the teeth and the maxilla, inspecting and measuring curved roots and canals, pulp stones, exostosis, secondary dentine, small pulp chambers, length and condition of root fillings, foreign bodies in the canals, old roots left after extraction, faulty bridge work, pericementitis, alveolar abscess, empyema of the antrum locating the position of abnormal antra, necrosis, absorption of alveolus subsequent to old age or extraction of teeth, chronic fistulas, pyorrhea, showing the amount of absorption in order to determine whether the prognosis is good for contemplated treatment, epulis, osteomas, odontomas and tumors of the oral cavity in general." When you have finished putting down this list you will probably think that there are not many conditions left to the dental surgeon. And you will wonder whether all this is true. Your friend, if he has had much experience, will turn to his card index of radiographs and take

out picture after picture with appended history, and show you cases of each one of the pathological conditions he has enumerated to you, and your doubt will turn to wonder. On the other hand, you may not be so lucky in finding as good a friend who will give up his time in explaining to you the advantages of the X Ray, but will let you go your way in blissful ignorance of the value of so useful an agent.

While you are in college you will have a short course in Radiology that will interest you for the time being, but which interest, in all probability, will be absorbed in the general rush and scramble to get through college ahead of your fellow classman with the least possible study and with the highest honors, giving time only to what *you* consider will be your hard subjects when you come to the final spurt for the much coveted D. D. S. You will attain this; subsequently, you will pass your State Board; and eventually you will, with the greatest of pride and considerable swelling of the chest and head, hang out your shingle in a part of the community where you think you will have more chance than your neighbor to rapidly acquire a practice, and reap a golden harvest. Your ambition may perhaps be realized *at once,* but alas! fate seems to have, in the majority of cases, decreed otherwise; and the chances are that you will have often to sit alone in your office waiting for the expected patients, and look out of the window only to see the steady stream of patients passing up the stoop of the house opposite, where Dr. Blank lives. You will then, if you are at all human, feel the first qualms of envy and you will ponder why it is Blank has such a good practice. You will say to yourself that he is a young man, too, and only graduated a few years ago, and you will fail to understand what great power he has that you do not possess. You will then sit down and read the dental journals, and try to improve your education and polish off the rough work as it came through the mill of your college career. Then it is that your thoughts may for the first time go back over your years at college, and you will think of your Radiology course, and remember the interest

it awakened in you at that time. This may even be brought to your mind by several articles on X Ray in the current journals. You will wish your course had been longer, and you will dig out your old and now-forgotten note books and you will find a *very few* notes on the subject, and you will wish, *I know you will* (many others have, and they have told me so), that you had only given the subject more attention and had taken more notes when you had the opportunity. You will hunt through your journals and you will probably discover some very interesting article on the subject, although somewhat out of your depth, and *behold!* you may even find one by your now much-hated rival, Blank, from across the street.

All this may happen, and again it may not occur at all. On the other hand, you may go years without more than a lingering occasional thought to the subject, but *the time will come eventually!* Just as surely as the profession has advanced to what it is, so *surely* will the time come when every dentist will have to *admit Radiology as an integral and necessary part of his profession.* This is no idle prophecy built on air castles, or the outcome of an enthusiastic desire to see it so; but I assure you, these statements are based on facts; and statistics will bear me out in showing the ever-growing demand for radiographs made on the specialist by the dentist; and the wonderful increase in the sales of the manufacturers of dental apparatus for X Ray work. It is for this reason that I am urging *one and all of you* to give the matter some thought and go out from your Alma Mater with some idea of the value of one of the most wonderful and useful weapons nature has given the modern dentist with which to fight against the difficulties and doubts that must arise in your work. Not only do I ask you to understand the subject, but I ask you *individually* to make *one trial of its value* on the first case you have occasion for it in your practice, and to judge *for yourself* whether or not what I say is true. You do not have to instal a complete set of apparatus in your office to do this; you can send the case to a specialist who will, within twenty-four hours, send you

a finished radiograph to study and determine the course of treatment. Do you think it is right to ignore the possibility of proving the exact conditions of a doubtful case? Is it just to yourself and your patient not to take every means within your power to ascertain the true condition of their case before you proceed to operate?

Answer these questions in the negative, and you will perhaps discover why your rival Blank has been so very successful.

NOTES

CHAPTER I.

Early Investigations and Discovery of the X Ray

Michael Faraday was the pioneer investigator of electrical currents and vacuum tubes. As early as 1838 he conducted a series of experiments with an electrical discharge through rarified gases, and invented the terms 'anode' and 'cathode' for positive and negative electrodes. His researches are now historical, inasmuch as they opened up a new field of investigation that was in time to bear fruit in the marvelous, though accidental, discovery of the X Ray.

Faraday was followed some time later by Gassiott, whose ideas were afterward carried out by Geissler, of Bonn, the first to construct the tubes that now bear his name.

Up to this time the investigations proved but little of importance, beyond the fact that any rarified gas gave off a peculiar glow, or phosphorescence, when subjected to an electrical discharge of high potential. This phenomenon became known as *'fluorescence.'* Air produced a pale violet glow, hydrogen a red, and carbon dioxide a steel-blue shimmer. Professor Hittorf, the celebrated electrical physicist, of Munster, next experimented with a Geissler tube of higher degree of exhaustion. He noticed an increasing resistance of the electrical current to the coefficient of rarification, he also found that the color of the gases under fluorescence varied with this increased degree of rarification and that the glow proceeded in straight lines from the negative electrode, casting a shadow of an interposed object upon the wall of the tube, and he furthermore disclosed the fact that these rays were capable of deflection by a magnet.

Doctor Crooks, afterward Sir William, was the next investigator to enter the field of research, and in 1878 made some

interesting announcements that did a great deal toward popularizing the subject. He experimented with the rectilinear rays of the Hittorf tube and devised the theory that the rectilinear path was caused by the current attaching itself to freely moving molecules of gas as it left the cathode, and proceeded in parallel lines with great velocity, and bombarded the opposite side of the tube, or other intervening object, with terrific impact. Sir William Crooks also succeeded in focusing these rays of rapidly moving molecules by curving the cathode, thus giving to it the form of a concave mirror, and thereby projecting the rays to a common point, instead of in parallel lines. Objects placed at the focus of these rays were heated to whiteness. This was supposed by Doctor Crooks to be caused by the bombardment from the enormous quantity of projected molecules.

Simultaneously with this announcement by Sir William Crooks, M. Goldstein came forward with the theory that the phenomenon was caused by a transmission of energy, and not by the bombardment with actual particles; but he could not give any definite explanation of his 'transmitted energy.'

Professor Weidemann, of Leipsic, in 1883, was the first to ascribe to the "Cathode Rays," as they began to be called because they emanated from the cathode electrode, the possibility that they were in reality light waves of extremely short wave-length at the remote end of the spectrum, far beyond the violet rays. Paul Lenard, a pupil of the famous Professor Hertz, also believed in this hypothesis, and in a series of experiments conducted at Bonn, proved conclusively that there was not only evidence of cathode rays outside of the generating Hittorf's or Crooks' tube, but that, furthermore, the rays even penetrated a thin sheet of aluminum foil, a fact that none of the investigators previous to this had ever suspected.

Prof. J. J. Thompson, of the Cavendish Laboratory at Cambridge, by an ingenious method afterward succeeded in actually measuring the velocity of these cathode rays, which he approximated to be about 200 kilometers, or about 124

miles, a second. It might be well to mention in reference to Professor Thompson that he advocated still another theory in regard to the nature of the cathode rays, similar to, yet differing from that of Crooks, namely that the molecule of electrically charged gas, or atmosphere, splits up into two or more 'ions.' This term, meaning 'traveler,' was so named by Faraday who has added largely to the nomenclature of electrical science, a term which, however, had long been used in connection with such electrically charged portions of matter as were known to exist in the passage of a current of electricity through a liquid.

After a long period of dormancy following the assertions of Paul Lenard, the world was once more aroused, in the year 1895, by the proclamation of Prof. Wilhelm Conrad Röntgen, that he had discovered an entirely new ray differing from any of the cathode rays that had formerly existed.

Like many other great discoveries, it was brought about through the accidental grouping of apparatus and conditions that were just ripe to disclose to the unsuspecting investigators facts that had been taking place time and again unobserved and unrecorded. In many cases it has taken but a simple incident to disclose to the ever receptive and gifted minds of our great inventors a new truth that has existed for untold years, and needs but the spark of intellect to develop and fan into life a new wonder that would in time revolutionize its own field of application.

So it was that Professor Röntgen, while experimenting with a Hittorf tube of high vacuum accidentally stumbled upon a discovery so remarkable and unbelievable at first, that scientists and laymen alike, from every quarter of the globe, paused in their daily occupations and gazed with amazement and incredulity at the first printed and brief reports of this most wonderful discovery. "A new ray had been discovered by means of which it was possible to look through opaque substances!"

Authenticated and more detailed reports were soon promulgated, and it developed that another instance had occurred where accidental grouping of conditions had born fruit little suspected by the now renowned investigator. The conditions were these: Röntgen had covered his vacuum tube with black cardboard. He had also coated another piece of cardboard with the crystals of barium-platino-cyanide, which he was testing for its fluorescence under cathode rays. This fluorescent 'screen' he had placed against a table in his laboratory to dry on the opposite side of the room from the vacuum tube. Then to test the tube he turned out the lights and switched on the current, passing the high potential discharge through the Hittorf tube covered with black cardboard. He then suddenly became aware of the fact that the barium-platino-cyanide screen was glowing brilliantly on the other side of the room, and furthermore in crossing the room to examine it, he passed between the covered tube and the screen, and was amazed to find that a shadow was cast upon the screen! It was only this that was needed to set this experienced investigator directly upon the correct solution of the apparent mystery. He at once suspected that a new ray had been found that had penetrated the black cardboard covering of his tube and affected the screen. He now turned the screen around with its cardboard back toward the tube. The fluorescence still continued on the crystal-coated side. The new ray had also penetrated through the back of the screen. He next took a large book of a thousand pages or more, and held it between the screen and the covered tube; still the glow persisted. The climax was reached when on holding his own hand between the tube and the screen he saw to his utter amazement depicted before him the complete shadowgraph of his hand, and more wonderful yet, the *bones* were outlined in solid black through the less dense flesh of the hand!

He further discovered that these unknown rays had an active infiuence on a photographic plate, and that shadowgraphic

pictures of the bones of the hand could be obtained in this manner.

This revelation was received by the scientific world with intense interest, and the enthusiasm of the medical profession was henceforth enlisted.

In Professor Röntgen's original communication to the Wurzburg Physico-Medical Society, dated December 1895, he describes some of his experiments and the conclusions that he deduced from them. Among other things he showed that the rays were not polarizable, nor could they be reflected, consequently he found that they could not be concentrated by lenses. He also discovered that the transparencies of different bodies under these rays depended entirely upon their density.

He gave to these wonderful and mysterious rays the name of the algebraic unknown quantity 'X,' and by this name, it is known to-day, notwithstanding the subsequent classifications of the ray and the bestowing upon it of a more accurate and dignified appellation. X Rays they were known as, and to the vast army of experimenters that have taken up their investigations X Rays they will always remain, an excellent example of how a popular misnomer may find its way into the nomenclature of scientific literature.

Professor Röntgen concluded his original paper with the hypothesis that these new X Rays were perhaps due to longitudinal vibrations of the ether.

Since that date there have been a large number of investigators in the field, many of whom have advanced some hypothesis or another concerning the exact nature of Röntgen's X Rays, but the old theory that Professor Weidemann brought forward in 1883, in reference to the cathode rays, was applied to the Röntgen radiation and is now the only explanation that has survived the critics of the scientific world.

We will now consider this present theory regarding the nature of the 'Röntgen Rays.'

THE COMPLETE SPECTRUM

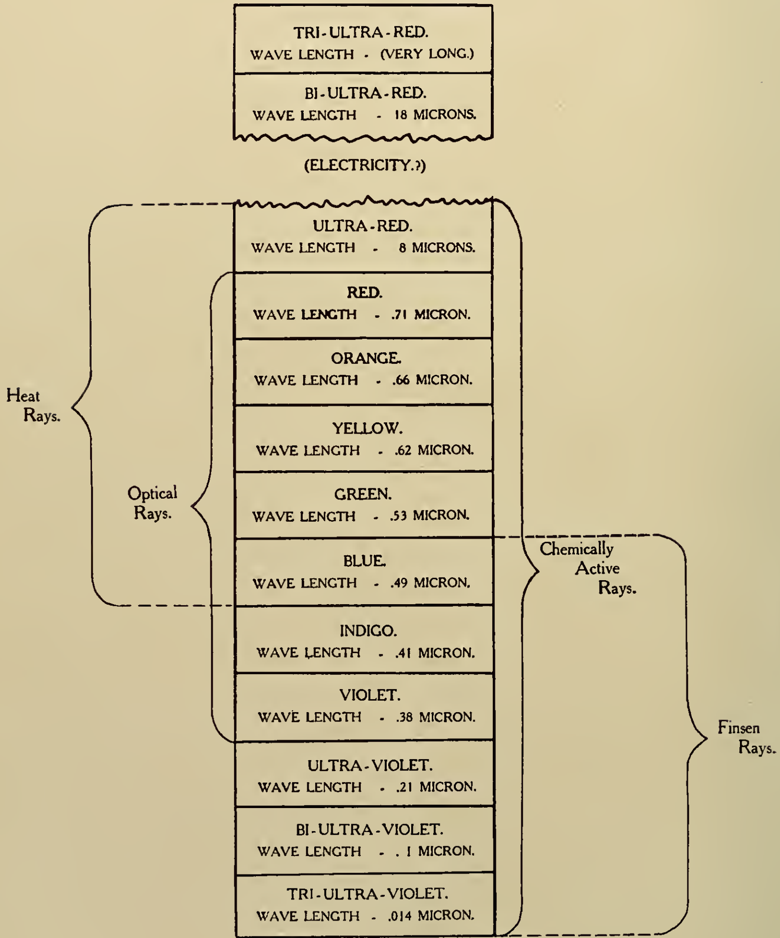

Figure 1—(see page 19)

CHAPTER II.

The Complete Spectrum—Invisible Rays—The Rays Comprising the Study of Radiology—General Properties

Figure 1 represents a diagram of the complete spectrum. You have probably from your physics associated the spectrum with the seven primary colors, viz.: violet, indigo, blue, green, yellow, orange and red, but the complete spectrum shows the presence of rays, both above the red and below the violet. The three rays above the red receive their names from their relation to the nearest visible ray, which is red: the first is called ultra red (meaning "beyond the red"), next, we have the bi-ultra red (meaning "twice beyond"), and in the same manner tri-ultra red indicates a group of rays that is still further removed, and might therefore be considered as three times beyond the physical red ray.*

Between the ultra red and bi-ultra red divisions there exists a break in the spectrum. Just what group of rays belong in this space we have so far been unable to determine, although the theory has been advanced that all electrical phenomena occupy this gap. This very likely hypothesis will never be proved until we are able to determine, with some degree of accuracy, the wave-length of electricity.

The ultra red rays are heat rays. The entire phenomena of heat are grouped in this division. They are invisible to the eye and their presence is known only by their effects, which are thermal in nature. Just above the break we have the bi-ultra red or magnetic rays. That part of physics which we know under the general term of 'magnetism' is included as belonging to this group, or division, of the spectrum.

* This nomenclature, "bi-ultra" and "tri-ultra," was suggested by the author in 1904 to take the place of the terms "ultra-ultra" and "ultra-ultra-ultra." See *Medical Record* of January 16, 1904—"The Röntgen or Tri-ultra Violet Rays, Their Nature, Applications, and Dermatological Effects."

Above the bi-ultra red comes the tri-ultra red, or those long rays of the ether, called Hertzian rays, now utilized in wireless telegraphy.

In all probability we have the following sequence: starting with the visible rays of red, which are to a certain extent heat rays, there is a shading off gradually to the invisible rays of heat, which are termed ultra red. Again we have a shading off from the pure effects of heat to the thermo-electrical phenomena. Then probably to the pure electrical phenomena, which are supposed to occupy the break above the ultra red rays, then to the electro-magnetic phenomena as we approach the bi-ultra red. Next the phenomena of pure magnetism, then those long magnetic rays of the ether, and finally the longest non-magnetic Hertzian or tri-ultra red rays.

The only difference between any of the rays in the complete spectrum, from the tri-ultra red at the top to the tri-ultra violet at the bottom, is the wave-length. If we had any means of changing the wave-length of one ray to that of another, we would also change its characteristics, for example (the wave-lengths are given on the diagram under their names), take the orange ray with the wave-length of .66 of a micron (a micron equals one millionth of a meter), and suppose we had some means of shortening this wave-length to, we will say, .014 of a micron, we would then change the orange ray into the tri-ultra violet. The orange ray would lose its color, it would become invisible and it would take on the characteristics of the tri-ultra violet, or in other words it would be converted into the X Ray, with all the properties of the X Ray. With the means at present at our disposal it is *impossible* to make the change in this particular case, but there are some instances where we *can change* certain rays into certain other rays, as we will see later on.

The tri-ultra red, or the Hertzian rays, are the longest of the spectrum rays and have no approximate wave-length. It is the only group of all the rays in the spectrum that varies to any great extent in wave-length, and it is to this fact that we

owe most of the improvements in wireless telegraphy. It makes it possible for an operator in one section of the country to communicate with any given station in any other part of the country, by turning his system to the same length of wave as that of the one which he wishes to call, thus securing selectivity in sending wireless messages.

You will note from the diagram that the wave-length gradually decreases from the top as you go down toward the bottom of the spectrum. Starting with the longest rays of the tri-ultra red, we come next to the bi-ultra red of 18 microns; then the ultra red, 8 microns; then the red rays, .71 of a micron; the orange, .66 of a micron; yellow, .62, and so on, till we get down to the ultra violet with a wave-length of .21 of a micron. Below this we have a still shorter ray, the bi-ultra violet, with a wave-length of .1 of a micron, and finally, the shortest of all known rays, *the tri-ultra violet,* or the X Ray, with a wave-length of .014 of a micron.

The three groups of rays that we have to consider under the general heading of Radiology, particularly in their application to Dentistry, are the ultra, bi-ultra and tri-ultra violet rays. We will consider first their general properties, that is, properties that are common to them all, perhaps not to the same extent or to the same degree. Then we will consider them as to their specific properties, that is, the properties and characteristics that each one has in particular.

The first general property to be considered is the *penetrative power.* They all three have a certain penetrative power, and the extent to which each one has this property is governed by a law which we know as the *"Law of Penetration."* This may be formulated as follows:

> "The penetration varies inversely with the wave-length, and also with the density and thickness of the substances to be penetrated."

This means that the shorter the wave-length the greater the penetration, and conversely, the longer the wave-length the less the penetration. The ultra violet is the longest of the

three rays, it therefore has the least penetration. The tri-ultra violet or X Ray is the shortest, consequently it has the greatest penetration. Also the thicker and more dense the substance, the less readily will it be penetrated. Density and thickness, however, are not the same thing. We can have a block of wood measuring one cubic inch; we can also have a block of lead with exactly the same volume, namely, one cubic inch. One is as thick as the other, but the lead is very much denser, as is shown by its specific gravity. The specific gravity is, therefore, the direct index for the density, and the greater the specific gravity the denser the substance, and the less readily will it be penetrated by these three rays.

Another general property of the three rays is their *therapeutic power,* which varies to some extent and with different pathological conditions. These we will consider separately.

The third general property is the *chemically active power* of the three rays. They all have the power of producing certain chemical changes or reactions in certain substances, not to the same extent, but inversely proportional to the wave-length. This property is not confined to these rays alone, but referring to the diagram we will see bracketed as the 'chemically active' rays, the tri-ultra violet to the red, inclusive. The red is the least chemically active and the tri-ultra violet the most. It is for this reason that we use a red light in the dark-room when manipulating photographic plates and films. The sensitive plate is not affected by the red light unless it be exposed to it for a long time. Since the red is so slightly chemically active it does not affect the sensitive emulsion of the plate or film by producing chemical changes in the salts. The orange is slightly more chemically active, and we can use it in the dark-room also, where we have a slower emulsion of plates and films, or where we have printing papers that are not as sensitive. The yellow and the green are a little more actinic or chemically active, while the blue is still more so. The indigo and the violet, and particularly the ultra violet, are also highly actinic. The bi-ultra violet is even more actinic, while the tri-ultra violet,

or the X Ray is the most actinic of all known rays. We can effect the sensitive emulsion on a photographic plate after the tri-ultra violet has passed through a block of wood ten or twelve inches thick, or even through a brick wall.

Another general property of the rays which is closely allied to the chemically active power, is that power which the three rays have of producing fluorescence in certain substances. It is the phenomenon that results when we expose certain substances to these three rays, the substance giving off a peculiar glow which resembles phosphorescence, and which we call fluorescence.

NOTES

CHAPTER III.

Ultra Violet Rays, Their Nature, Characteristics and Applications

We will now consider each of these three rays separately. First, take the *ultra violet,* with a wave-length of .21 of a micron, the least penetrative of all these three rays. A single sheet of glass is sufficient to cut off absolutely all ultra violet radiation. The ray will not penetrate a substance with a density or specific gravity as great as glass. We therefore take 'glass' as the limit of penetration for the ultra violet ray.

The ultra violet ray is produced in two ways: first, we find it in a free state, in the presence of an electrical spark. Under all circumstances and conditions, *wherever we have an electrical spark, ultra violet rays are generated spontaneously.* It makes no difference where the spark occurs, whether it is the spark that we find in an arc lamp, or whether it is the spark occurring in the spark-coil of an automobile, or whether it is the lightning that we see in the clouds; they are all sparks and *they all produce ultra violet rays.* It does not matter whether the spark takes place in the air or in a vacuum, except that in a vacuum the spark is invisible and takes place as a discharge or *ionization.* We do not use these ultra violet rays that are produced in the presence of a spark, except under rare circumstances, where we produce the spark with the intention of getting the ultra violet ray from it. In all other cases the ultra violet ray is thrown out on the atmosphere as an infinite radiation. We also find ultra violet rays directly in nature, in the presence of DIRECT sunlight. A single pane of glass will cut off the ultra violet rays—we therefore have to have the sun's rays in the open and not coming through a glass window. It is supposed by some scientists that even these ultra violet rays come originally from an electrical spark, this spark taking place in

the atmosphere of the sun, as an ionization of the gases that envelop that planet. Of course this is only a theory and lacks the necessary proof, although the supposition seems plausible.

The therapeutic effects of the ultra violet rays are very marked in tubercular conditions of the skin. The disease which is known as 'lupus vulgaris' yields most readily to ultra violet radiation. Doctor Finsen, of Copenhagen, Denmark, was one of the first to utilize this property of the ultra violet rays, and he did so in an especially constructed lamp. His apparatus consists first of a series or 'bank' of arc lights, the electrodes of which, instead of being constructed of carbon, as most arc lamps are that we use for illumination, are made of iron or copper, as he found that these two metals when used as electrodes gave off much richer radiations of ultra violet rays. These rays he collected by means of a parabolic mirror and concentrated them through a large telescope, the inverted end, or objective, of which was presented to the arc lamps. The lenses of this telescope were of peculiar construction; they could not be made of glass, as the ultra violet ray would not traverse them. He had to construct them of a substance that had a lesser specific gravity than glass, so he used quartz and colored it cobalt blue, which absorbed all the other light and heat rays of the spectrum, and allowed only the blue, indigo, violet and ultra violet rays to pass. You will see in Figure 1 these four rays bracketed and classified as 'Finsen Rays.' The small end of the telescope was focused upon a patient who reclined on a couch below the apparatus, and these powerful rays, particularly those of the ultra violet, when allowed to radiate over a surface of lupus, caused a destruction of the tubercle bacilli and cured the lesion. The percentage of cures has been estimated to be as high as 97% of cases when treated with Finsen rays, and the only reason that it is not 100% is that we have to allow about 3% of failures due to faulty technique on the part of the operators, and also of the inability of patients to continue the prescribed treatments.

There are a number of other skin diseases for which the ultra violet ray also possesses a therapeutic value, but perhaps not to as great an extent as those shorter rays which we will now consider as the bi-ultra violet.

NOTES

CHAPTER IV.

Bi-ultra Violet Rays, Their Nature, Characteristics and Applications

The *bi-ultra violet ray* has a wave-length of .1 of a micron. It has a greater penetrative power than the ultra violet; it will pass quite readily through thin sheets of aluminum, one of the lightest of the metals, but will not pass through heavier metals. Aluminum is, therefore, the limit of penetration of these rays.

Bi-ultra violet rays are obtained in two ways:—First, by the breaking up of the ultra violet into still shorter rays in the presence of a vacuum tube; and directly, in nature, in the presence of all radio active substances, such as radium, actinium, polonium, uranium and many others. These rays differ but very slightly from the ones generated in the vacuum tube, their characteristics are almost identical, and it is only in the wave-length which is slightly shorter that we note any distinction whatsoever. Bi-ultra violet rays are used quite a little in the treatment of superficial cases of cancer. They are also used to a very great extent when combined with currents of high frequency and high potential in the modern treatment of rheumatism; very good results can be obtained by this method. Cases of ankylosed and stiffened joints can be broken up and deposits of uric acid dissolved, but the best results are only obtained when a correct technique is used in the administration of the treatment, together with proper diet and alkaline medication.

In dentistry we utilize the bi-ultra violet ray in the treatment of pyorrhea alveolaris, by means of the author's vacuum electrodes, especially designed for the purpose, with excellent results when the technique is carefully and faithfully carried out.

The therapeutic value of the rays given off by radium is so closely identified with the vacuum tube rays that the results have proven to be about the same. You will remember when radium was first discovered by those two great French chemists, Monsieur and Madame Curie, how all the newspapers and the medical and scientific journals took up and exploited the wonderful new element, 'Radium.' To-day we do not see quite so much about radium in the scientific journals and practically nothing in the newspapers. Does that mean that radium has lost its power, or to what do we attribute this falling off in the use of radium? The reason is this: It was found exceedingly difficult to extract the pure bromides of radium from the ore, the process requiring a long time and a great amount of work which, therefore, made the cost of pure radium enormously high. We have not one pound of pure metallic radium in the world to-day, and if we had, it is estimated that it would cost just about $33,000,000. With a small vacuum electrode that can be purchased for about $1.50 we can generate bi-ultra violet rays of equal power and volume to those emanating from ten pounds of radium. That is the explanation!

There are certain cases, however, where the rays given off by radium can be used where we cannot use the vacuum rays, principally in the treatment of cavity conditions. For example, in the treatment of a case of cancer of the stomach, we take a small vial of radium, place it in a stomach tube and lower it directly into the stomach in close proximity to the diseased lesion. This you cannot do with a vacuum electrode. Radium has no application to dentistry to-day, although at one time its use was advocated by two Holland dentists who thought that its analgesic powers could be utilized in the treatment of pulpitis by the placing of a tiny vial in the root canal of an aching tooth. The dental profession, however, did not take up the idea and preferred the inexpensive use of arsenic or 'pressure-anesthesia' and the removal of the offending pulp and filling the canal.

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CHAPTER V.

Tri-ultra Violet Rays, Their Nature, Characteristics, and How Generated in a Vacuum Tube

The wave-length of the tri-ultra violet ray is .014 of a micron. It is situated at the very lower end of the spectrum and, being the shortest wave length of the three rays, it has, therefore, according to the law of penetration, the greatest penetrative power. It will penetrate all substances—even gold, platinum and silver—the densest metals, in thin sheets. The therapeutic properties of the tri-ultra violet or the X Ray are very marked; one of its principal effects being its analgesic power. We frequently find that in the short exposure necessary for the taking of a radiograph the pain from an acute attack of neuralgia of the fifth nerve, or from an ulcerated tooth is quite relieved, and its effects sometime seem almost magical. Nevertheless, it is a most dangerous method to use for the relief of pain, and should *never be resorted to, particularly by the dentist,* as there is always the temptation to repeat the dose too often at the urgent request of the patient, and consequently to produce conditions that are very hard to heal. However, these conditions we will take up in a subsequent chapter.

The X Ray is used in many cases of cancer with very good results, and where the cancer is superficial we have very often been able to attain a cure. If the cases are those of deep-seated tumors it is more difficult to get good results, inasmuch as we have to penetrate healthy tissue to get at the cancerous lesion. Cancers of the skin, therefore, can be said to yield very readily to X Ray treatment. Those situated near the surface, as for instance, cancers of the breast, are more difficult, but very good results have been obtained, particularly if we can operate first. The modern technique in the treatment

of cancer is to operate first, *wherever possible,* and immediately after an operation to follow up with a series of X Ray treatments, *even through the dressings.* This, in most cases, prevents recurrence. There are many skin diseases that yield more or less to X Ray radiation, among which many be mentioned lupus vulgaris; lupus erythematosus; carcinoma, external, scirrhus and epithelioma; sarcoma; enlarged glands, scrofulous or otherwise; goitre, simple and exophthalmic; sycosis and favus; molluscum contagiosum; phthisis, pulmonary and laryngeal; rodent ulcer; hypertrichosis; pruritus; eczema; acne; warts, etc., etc.

Let us now see how we can obtain these three rays. We will refer to Figure 2, which represents the interior of a large X Ray tube.

We will suppose that we have a sphere of glass from which most of the air is exhausted, consequently there exists a state of partial vacuum. Vacuums are referred to as "high," "medium" and "low," a complete vacuum being impossible to attain. A high vacuum is where only one millionth part of the original air remains; or an equivalent pressure of about .0003 millimeters of mercury, while a medium vacuum would have one hundred thousandth part of the original air, and a low vacuum would be where one thousandth part remains, or an equivalent pressure of about .005 millimeters of mercury.

In this sphere of glass (A) or X Ray tube, as we will call it, we have the condition of medium vacuum, i. e., a hundred thousandth per cent. vacuum, which is about the degree of exhaustion necessary for satisfactory dental work. In this tube we have two metal electrodes represented in the diagram by the lines DWE and FXG. They are disks of metal placed at opposite sides of this tube and parallel with each other. They are connected by wires passing through the glass wall to terminals on the outside, C and B, which can in turn be connected with the source of electricity. We will now pass a high potential current of electricity through this tube, i. e., a current of from 60,000 to 180,000 volts. This high potential current, the nature of which we will take up a little later, enters

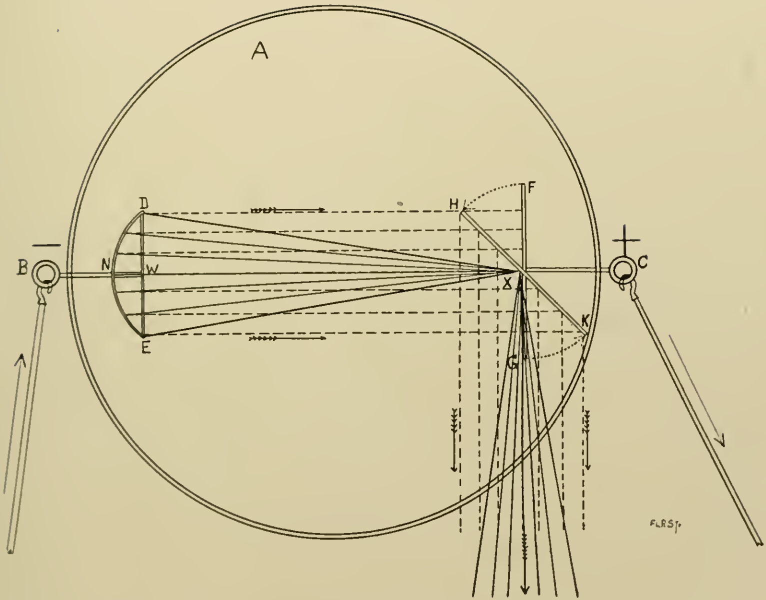

Figure 2—(see page 34)

at the cathode or the negative side, marked in the diagram by the minus sign, passes through the tube across the vacuum gap and impinges upon the anode or positive electrode marked by the positive or plus sign. The velocity of the electric current through a low vacuum has been estimated to be about 124 miles per second. The current leaves the cathode disk (DWE) in the form of an invisible spark or electrical discharge. As we have said, wherever an electrical spark takes place ultra violet rays are produced; therefore, ultra violet rays are spontaneously produced all over the surface of this cathode disk. These rays take the path of the current; they travel through the tube with the same velocity (about 128 miles per second in a medium vacuum), in parallel lines, as indicated by the dotted lines in the diagram, until they strike upon the anode FXG, at the positive side of the tube.

The enormous velocity under which these rays travel causes a shortening of the wave length. This may be illustrated by a simple simile. Take a long coil of rope and fasten one end to a post, and stand off some distance with the other end of the rope in your hand; very *slowly* shake the end *up and down,* and you will start a series of large waves, or a *wave motion,* in this rope. If you increase the velocity with which you shake this rope up and down, your waves will become shorter. This is analogous to what takes place in the vacuum tube. The great velocity under which these rays travel causes the wave-length of .21 of a micron to be reduced to about .1 of a micron. *The ultra violet rays, therefore, lose their individuality and take on the characteristics of the bi-ultra violet ray,* which has a wave-length of about .1 of a micron. Just where this transformation takes place we do not know. It may be close to the cathode or it may be close to the anode, or it may be just half way between; it makes no difference as to the ultimate result. The bi-ultra violet rays, when once formed by the breaking up of the ultra violet into the shorter wave-length, continue until they at last strike upon the metallic surface of the anode. *Here they undergo their second transformation.* The original ultra violet

rays had been reduced in wave-length to as great an extent as possible, by the velocity alone under which they were traveling. Now add to that velocity the sudden force of impact against the solid anode and we get a still greater reduction in the wave-length. *The bi-ultra violet rays are shattered.* The wave-length decreases from .1 of a micron to about .014 of a micron; or, in other words, the *bi-ultra violet ray is transformed into tri-ultra violet, or the X Ray.* The greater the velocity with which these rays travel the greater will be the impact against the anode, and the shorter will be the wave-length resulting from the impact.

If the tube was actually constructed with the electrodes as represented by the lines DWE and FXG, in Figure 2, we would not, in all probability, get the double shortening of the wave-length. The bi-ultra violet rays would not be reduced to a wave-length as .014 of a micron, because, when they strike upon the anode, they would be reflected *directly back upon the approaching rays,* and would tend to retard these rays, consequently their force of impact would be considerably reduced. The reflected ray would not have as short a wave-length as it would if the approaching rays were not retarded.

To remedy this effect we change the position of the anode and swing it to an angle of 45 degrees with the vertical. The line FXG now becomes the line HXK. As the rays strike upon this surface they are reflected downward, and consequently will not tend to retard the approaching rays. Still it would be nearly impossible to obtain an X Ray picture from such a tube. The reason for this is that the rays emanate from a series of points upon the anode, instead of one single point. If the area of the surface of the cathode disk were one square inch we could readily conceive of one million points of electrical discharge from this disk. Each point of discharge would generate its own ultra violet ray. We would then have one million parallel 'beams' of ultra violet ray traversing the tube, and they would consequently strike upon the anode in one million points. From each point X Rays would be gener-

ated and we would therefore have X Rays emanating from one million points. You will readily see that a tube of that kind would be useless to take a radiograph with, since an X Ray picture is essentially a shadowgraph, and in this case there would be no sharp or distinct shadows. If you were to stand ten candles in a row in front of a screen, and then place your hand between the ten candles and the screen, there would be ten shadows of your hand thrown upon the screen, none of which would be very sharp. They would all be blurred and hazy; but if we were to merge all these ten candles into one candle of ten candlepower, we would have as a resulting shadow *only one* outline of the hand with ten times the intensity of shadow, but sharp and well defined. To accomplish this result in the X Ray tube we must bring these beams of approaching bi-ultra violet rays *to a point, and that point must be upon the surface of the anode.* We must therefore change the shape of the cathode disk. Instead of a straight disk, as shown in Figure 2, by the line DWE, we give to it the form of a concave mirror shown by the line DNE, and we place it at such a distance from the anode as to bring its principal focus directly to a point upon its surface.

This is one of the most essential principles in the construction of an X Ray tube. The tendency on the part of many manufacturers is to get an imperfect or 'coarse focus,' with the result that X Rays emanate from a series of points, instead of from one single point. Pictures made with tubes of this character are not as clear as they would be if the tube had a 'pin-point' focus. In purchasing a tube, when the manufacturer 'tries it out' for you, as he generally will, you should notice whether the point of light upon the surface of the anode is a 'pin point' or whether it is one-eighth or even one-quarter of an inch in diameter, as we sometimes find, and reject tubes where the focus is not sharp.

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SECTIONAL DIAGRAM OF X RAY TUBE

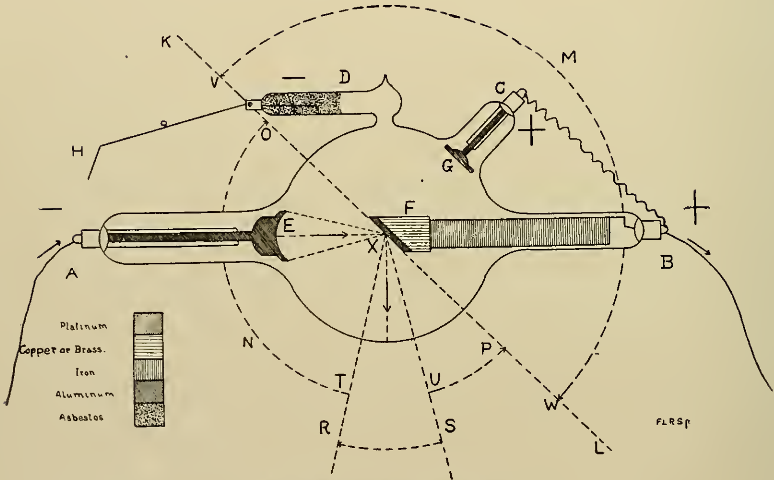

Figure 3—(see page 43)

CHAPTER VI.

The X Ray Tube

Figure 3 represents a sectional diagram of a modern X Ray tube. We note that the sphere of glass has two elongations at either end through which the electrodes FB and EA pass. These elongations separate the external connections for the high potential current, making a greater air gap for the current to jump than if the external connectors were on wall of the sphere itself as in Figure 2. This arrangement forces the current to pass through the resistance of the vacuum rather than overcome the greater air resistance from A to B on the outside of the tube. A plane, KL, passing through the tube and coinciding with the surface of the anode, divides the tube approximately into two hemispheres; the lower hemisphere ONP is called the *hemisphere of activity,* and the upper one, VMW, the *hemisphere of non-activity.* Anything placed on the lower side of the plane, KL, would be subjected to the radiation of the X Rays, anything placed on the other side of the plane, KL, would receive no rays whatever.

We note in looking at this diagram, Figure 3, the third electrode, CG, which is marked with the positive sign. We therefore infer that it must be an anode, and we note also that it is connected exteriorly by means of a wire to the main anode. The shape of the inside surface, G, is usually a flat disk. The purpose of this electrode is to act as a safety valve for the electrical current. It answers the same purpose to the tube as the safety valve does on the steam boiler of an engine. If we throw in too great a pressure of steam, the safety valve blows open and the surplus steam escapes, thereby preventing an explosion of the boiler. The same thing takes place in the tube. If we throw in too heavy an electrical discharge, so great that the

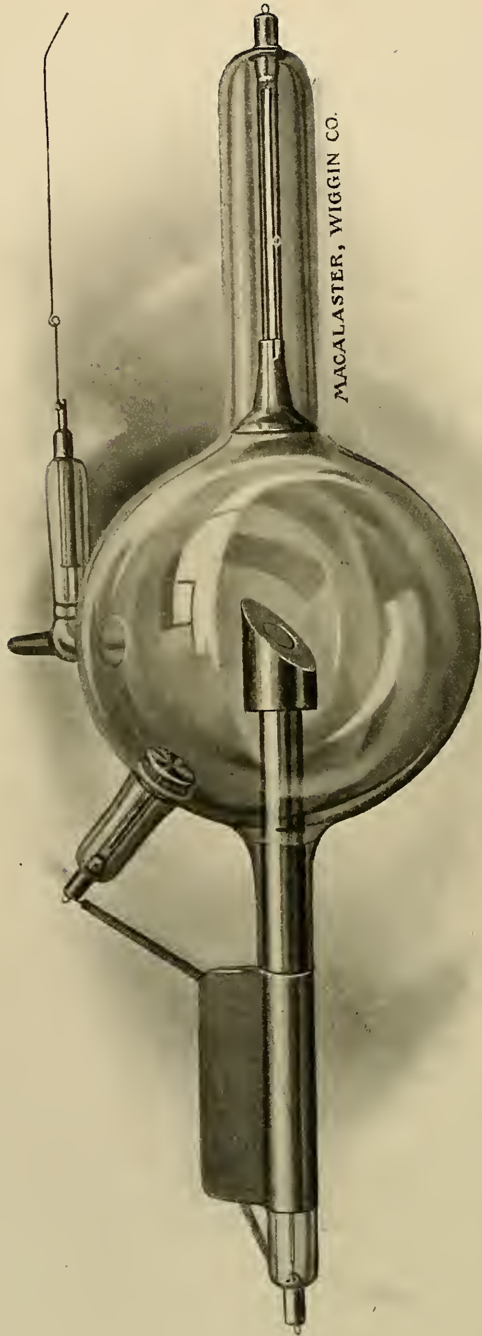

Figure 4—(see page 45)

capacity of the main anode cannot carry it off, the secondary anode takes up this surplus electricity and conveys it out of the tube and joins it to the conducting wire, returning it to its circuit, consequently preventing the current from striking the glass wall of the tube and puncturing it.

All tubes are not constructed with this secondary anode. If the capacity of the main anode is large enough to carry off the heaviest current that we can force through the tube, there is no need for this extra electrode which is known by several names. It has been called a secondary anode, an auxiliary anode, and an anti-cathode, but the term principally used is the *bi-anode.*

The main anode of the tube is constructed of three metals: first a disk, which is generally made of an alloy of platinum and iridium, or even a tungsten button, to withstand the very *intense heat* of the electrical discharge, focused to a single point, together with the bombardment of the bi-ultra violet rays upon its surface. This heat is so intense that if we had but the disk of platinum alone it would be immediately melted. It is therefore necessary to construct it of platinum alloy of the highest fusing point, or else with a tungsten button set into a surface of copper or brass. We next back up this disk of alloy with a solid block, F, of copper or brass, the block in turn being mounted on a hollow iron core extending back into the narrow neck of the tube. The purpose of this iron core and solid block, back of the disk or *'target,'* as it is very often called, is to conduct the heat away from the surface, and distribute it, thereby reducing the intensity upon the surface of the target. Figure 4 represents an illustration of the modern type of X Ray tube, made by the Macalaster, Wiggin Co., of Boston, Mass.

Another thing you will observe *while the current is passing through the vacuum* is the green coloration in the tube. This green color is *not,* as many people suppose, the X Ray itself (which you will remember is *invisible*), but is due to the *fluorescence of the rarified gas* remaining in the tube after

partial exhaustion. The coloration depends on two things: first, on the kind of gas, and second, the quantity of gas present.

In the X Ray tube we have to deal only with one kind of gas, and that is the atmospheric air which it originally contained. Upon exhaustion we leave it in a rarified state, and therefore, in passing a current of high potential electricity through it, it gives off this peculiar glow or fluorescence. *This fluorescence, or coloration of the gas in the tube, serves us as a guide or index to the degree of vacuum, or exhaustion, of the tube;* in fact, we have *no other means of determining the quantity of gas in the tube.* Unfortunately there is no meter or gage that we can attach to the tube and take a direct reading of its state of vacuum. We have to rely on our experience in the judging of the coloration, assisted by the reading of the milliamperes passing, as to whether the tube has a proper degree of vacuum or not. We will consider the coloration of air at different degrees of rarifaction. We will start at very low vacuum and go up to very high. A tube of very low vacuum is red, and as the vacuum increases the red changes to violet, the violet to blue, the blue to green, then through all the varied delicate shades of green, from very dark to very light, until at last we come to a bright canary yellow of highest vacuum. The entire range of efficient work in an X Ray tube used for dental work may be classified under the different shades of green, from dark to light olive. Experience only will determine the correct shade of green for the taking of a proper picture of the part in question. The degree of vacuum of a tube means a great deal to the operator, because it governs the amount of penetration of the X Rays; the higher the degree of vacuum the more penetrating will the rays be, and the velocity with which the rays and electrical current traverse the vacuum will be greater. The rays are therefore broken into shorter wave-lengths, and under the law of penetration the shorter the wave-length the greater the penetration; the converse is true in low vacuum. In low vacuum tubes we have

a greater volume of rays, and therefore a better or more brilliant coloration than in the higher degrees of vacuum, because the resistance of the vacuum is not as great to the electrical current, and consequently more current passes through the tube and more rays are generated, but they lack the intensity because they do not travel with a speed sufficiently rapid to cause a breaking up into the *shortest* wave-lengths.

In the higher vacuum tubes, as the resistance increases to the electrical discharge, some of the current, instead of passing through the tube, jumps around the outside as a static discharge. In that case we only utilize part of the current, and therefore have a reduced volume of rays, but those rays travel with a greater velocity and generate more penetrating X Rays. A strange thing about all X Ray tubes is that, in an absolutely closed and hermetically sealed tube, the quantity of gas varies. This apparently paradoxical phenomenon can be explained by the fact that all substances are porous; porosity being one of the general properties of matter, and in the pores, or between the interstices of all matter, we have in most cases air. So in the metal parts, and even in the glass itself, of this tube, we have particles or molecules of air that have been held between the pores or interstices. Another principle of physics is that when bodies are heated they expand, and in the expansion they drive off the confined air. When we pass a current of electricity through the tube one of the first phenomena that occurs is the generating of heat in the metallic parts of the tube by resistance to the electrical current. Electrical energy is transformed into heat energy. The heat thus transformed causes the metals and the glass itself to expand. The air that was confined in them is therefore driven off and added to the supply already present in the tube, and consequently lowers the degree of vacuum. When the tube is allowed to cool again the gases are once more absorbed by the metals and by the glass that gave them off, but strange to say, a *little more gas is absorbed than was originally given out.* Just what causes this is not known, but the fact remains, and consequently we find that

the more we use a tube the higher vacuum it will become. Each time we pass an electrical current through the tube we will probably note that it is a little bit higher in vacuum than it was the time before.

Since the vacuum has a tendency to rise with use, it becomes necessary to have some means of lowering it at will. The attachment on the tube, used for this purpose, is illustrated by D in Figure 3. It is called the *regenerator* or *regulator.*

A small elongation projecting from the top of the hemisphere of non-activity is packed with a small wad of asbestos. There is a piece of platinum wire passing into the elongation connected with the exterior cap or terminal. To operate, we shunt the *reduced* electrical current from the cathode side into the regulator, either by a direction connection from the coil, or by causing the current to jump from the external cathode terminal A to an adjustable wire H, attached to the exterior regulator terminal, which latter is brought near to the cathode terminal when we wish to allow some current to be shunted through it. The current passing through the asbestos generates heat by resistance, which in turn causes the asbestos to expand and liberate the confined air, as there are many molecules of air held entangled in the porous asbestos. This confined air is driven off into the tube and so lowers the vacuum.

This is a very desirable form of regulator, inasmuch as we utilize it *with the current passing through the tube* and we can therefore proceed intelligently, having the coloration in the tube as a guide to the extent to which to lower it. When we reach the proper shade we disconnect the wire that is carrying the current to the regulator, or bend up the wire attached to the regulator terminal so that the shunted current no longer jumps its gap, and allow it to pass only from the main cathode.

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Figure 5

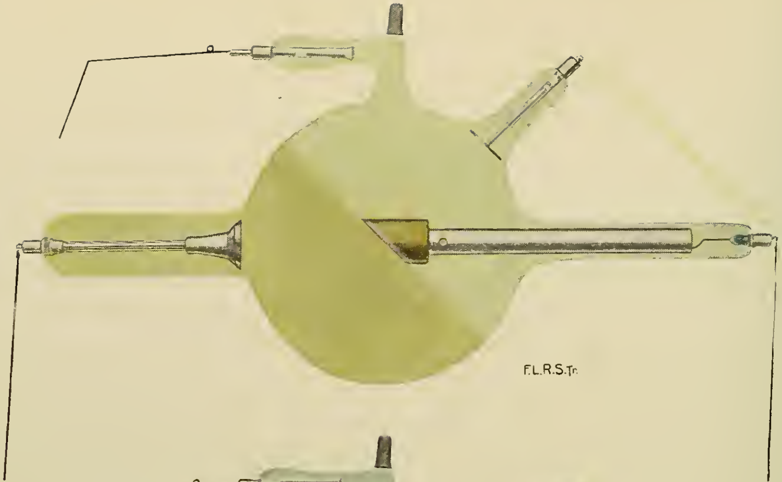


Figure 6

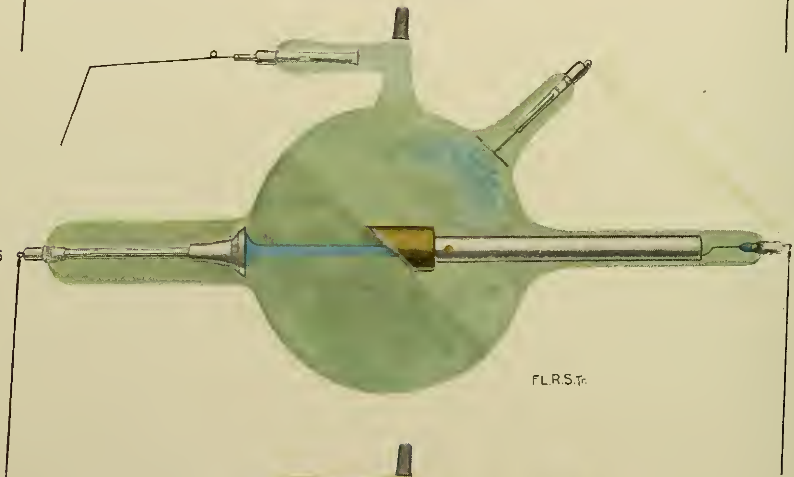
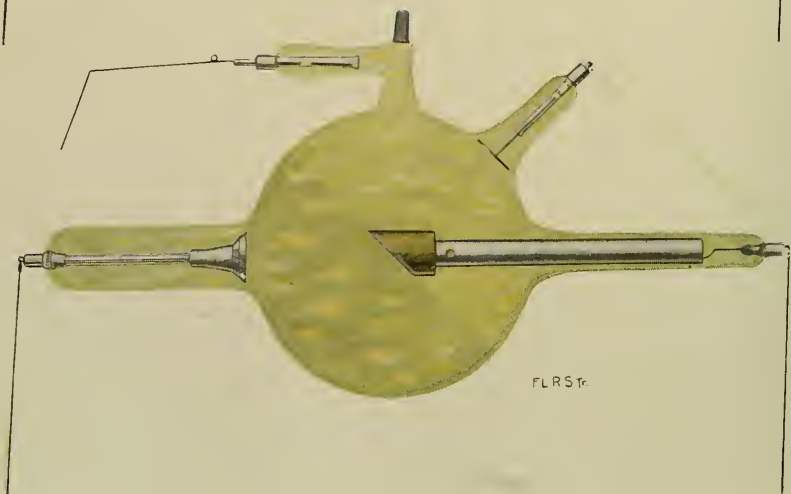


Figure 7



CHAPTER VII.

Symptoms of High and Low Vacuum—Remedies for Same

We will now consider the symptoms of low vacuum and symptoms of high vacuum, and the remedies for these defects. We will first suppose that the tube is working properly, with just the right shade of green to give us a good dental radiograph (Figure 5). We will allow a heavy electrical current to pass through the tube and heat up the metal parts so that some gas will be driven off, causing the vacuum to drop a little. How can we tell when the vacuum is dropping? What is the first change we notice? It is this: we note first of all a little puff of blue light right in front of the concave surface of the cathode. If we continue to lower the tube this blue puff of light, which resembles very much a little puff of smoke, gradually expands in the form of a cone, the apex of which extends toward the surface of the anode (Figure 6). If we lower it still more this blue light will at length bridge the gap between the cathode and the anode. The tube is then *too low* for a radiograph. When we first note the blue light we could still continue to take a radiograph, but it is a danger signal that the vacuum is going down.

The first thing, therefore, that we have to look out for is the appearance of blue light in the tube, and when we see any indication of it we know that the vacuum of the tube is getting low. We must be careful not to allow the vacuum to become TOO LOW, for if we do it will be nearly impossible to raise it again. By the time that the blue light reaches entirely across the tube it will be out of commission, as far as a radiograph is concerned. Let us suppose, nevertheless, that we *continue* to lower the tube or, rather, let us suppose that the tube has become punctured, the glass wall cracked, and therefore the

air from the outside is gradually forcing its way into the tube. We will follow the changes that take place in the tube until the air on the outside and the air on the inside have reached equal degrees of pressure. From the time when the blue light reached from cathode to anode we find that it will then extend and spread until the entire tube becomes of an even bluish color. Next we will note a little puff of pink light at the surface of the cathode, getting denser all the time in color until it finally becomes a decided red, and this red also takes the form or the path of a cone and travels from the cathode to the anode. It will then expand until the tube takes on a red coloration which indicates that the vacuum is *very, very low.* The next change we note is that this red coloration gradually fades away until we see absolutely no color in the tube, but instead there is a visible spark jumping from cathode to anode. When we see this we know that the vacuum in the tube has entirely gone, and there is the same pressure of air inside the tube as outside.

Let us now consider the symptoms of high vacuum. Again, suppose the tube to be working properly, with just the right shade of olive green. What will be the first sign that the vacuum is increasing? First the shade of green will become lighter and lighter with an ever-increasing tendency toward yellow. Then we will note little dancing bright yellow spots of light throughout the tube, not confined to any place, but moving around (Figure 7). At first there will be just a few small spots, but as the vacuum increases the spots get larger, and they multiply in numbers until we have large yellow circles traversing the tube. We know then that the tube is very high in vacuum. We can also hear a crackling noise, caused by the static discharge. The current is not all passing through the tube as it should, since the vacuum of the tube has become too great for all the current to pass through; therefore, *some* of the current passes on the outside and follows the glass wall of the tube. When these yellow circles of light appear in the tube, it is time for us to lower the vacuum. If when we

first place the tube in commission, after it has rested, and we note the yellow spots the instant we turn on the current, *do not lower the vacuum at once,* but let it run for a few seconds and see if the metals, on being heated, and giving off gas, will not lower the vacuum sufficiently. If this is not the case, we can then resort to our regulator to lower the vacuum. Sometimes when putting on a new tube, or one that has been used a great deal, and has had a rest, we may find that the vacuum is so high that the electrical current will not pass through it at all, but instead jumps across the terminals of the coil, in which case it should be lowered at once by the regulator. The degree of vacuum is often referred to, as governed by the number of inches of spark it will 'back up' on the coil. To test this, start the tube with the terminal gap wide open on the coil; now gradually bring the terminals together till the current starts to jump from one to the other, instead of passing through the tube. Measure this gap in inches.

When an X Ray tube has become too low there is nothing that we can do to bring it up, except to allow a *very small current* of electricity to pass through it; *in the opposite direction,* so that we barely see a glow in the tube. Let it run this way for some time, and if during that time the vacuum does not come up we know the case is hopeless, and our only remedy is to send it to the manufacturer, who will re-exhaust it. He will break the 'seal-off,' through which the gas was originally pumped out, and will let the air into the interior, and again pump it out to the right degree of vacuum. This is an expensive process and it is better to prevent the tube from running too low, by careful watching, and avoid the re-exhausting of the tube.

The remedy for high vacuum is simple, but we must be careful *not to lower it too much.* A tube of high vacuum has a smaller volume of rays than one of low vacuum, but the rays are more intense, because we have a higher potential current forcing its way through the high vacuum. The volume of rays being reduced in quantity, and the intensity being greater,

therefore the velocity with which the rays travel will be greater. Again, the velocity being greater than 124 miles per second, the bi-ultra violet rays will strike the platinum anode with an increased force of impact. The result is that the X Rays will be broken into still shorter wave-lengths, and by referring to the law of penetration, the shorter the wave length the greater the penetration; therefore, *we have, from a very high vacuum tube, more penetrative power,* although reduced in volume or quantity.

In low vacuum tubes the entire current passes through it and there is an increased volume of rays, but the intensity is not as great because the rays travel with a lesser velocity, and the *rays have less penetration.*

The following table of comparative properties of high and low vacuum tubes should be carefully studied, as a thorough familiarity with these properties is most essential to the radiologist.

COMPARATIVE TABLE OF HIGH AND LOW VACUUMS

HIGH VACUUM TUBES (Sometimes called 'hard' tubes.)	LOW VACUUM TUBES (Sometimes called 'soft' tubes.)
Electrical discharge or 'static' on outside of tube.	No electrical discharge or 'static' on outside of tube.
Coloration tending toward yellow, with bright yellow in places. (Remedy: lower vacuum with the regulator.)	Coloration tending toward blue-green with blue puffs of light in places. (Remedy: give tube a rest, or reverse current on *reduced* potential.)
Less volume, or quantity of X Rays.	Greater volume, or quantity of X Rays.
More penetrating X Rays.	Less penetrating X Rays.
Less contrast between blacks and whites, in radiograph.	More contrast between blacks and whites in radiograph.
More exposure needed as compared with medium vacuum tubes, due to lack of *volume of rays.*	More exposure needed as compared with medium vacuum tubes, due to lack of *penetration in X Rays.*
Low milliamperage in secondary circuit.	High milliamperage in secondary circuit.
Less danger of dermatological effects, due to greater penetration and less absorption of X Rays by the superficial tissues.	More danger of dermatological effects, due to less penetration and more absorption of X Rays by the superficial tissues.
Glass wall of tubes more apt to puncture.	Glass wall of tubes less apt to puncture.
Surface of anode less apt to burn out.	Surface of anode more apt to burn out.

CHAPTER VIII.

The Essentials of an Outfit—Methods of Generating High Potential Electric Currents—Electrical Measurements

There are four essential parts of an X Ray outfit for the dentist. First, the induction coil, or other means of obtaining our high potential current; second, the interrupter (providing an induction coil is used); third, the X Ray tube; and fourth, the X Ray 'tube-shield.' This last piece of apparatus is *essential to the health and protection of the operator,* and not to the working of the apparatus, but it is so important that we class it as one of the four essential parts of the outfit.

There are four methods in general use for the generating of the high potential current; we will consider them in the order of their efficiency.

First, the 'motor-generator-transformer' type, commonly known as the *'interrupterless,'* with a maximum output of 110,000 volts, *and as high as 200 milliamperes.*

Secondly, the *induction coil,* with a maximum output of about 120,000 volts in a 12-inch coil, but with a milliamperage of from 15 to 30.

Thirdly, the *static machine,* with a maximum output of about 200,000 volts in one of the largest machines, and about 2½ to 5 milliamperes.

Lastly, the *Tesla transformer,* with an average maximum output of about 60,000 volts, and only 1 or 2 milliamperes.

We will consider the types that we have mentioned, taking up first the most efficient, the 'interrupterless' type. This is an apparatus that represents the very latest achievement of the manufacturers. It is a type of apparatus that enables us to do instantaneous work in radiography. We will describe the construction of it very briefly.

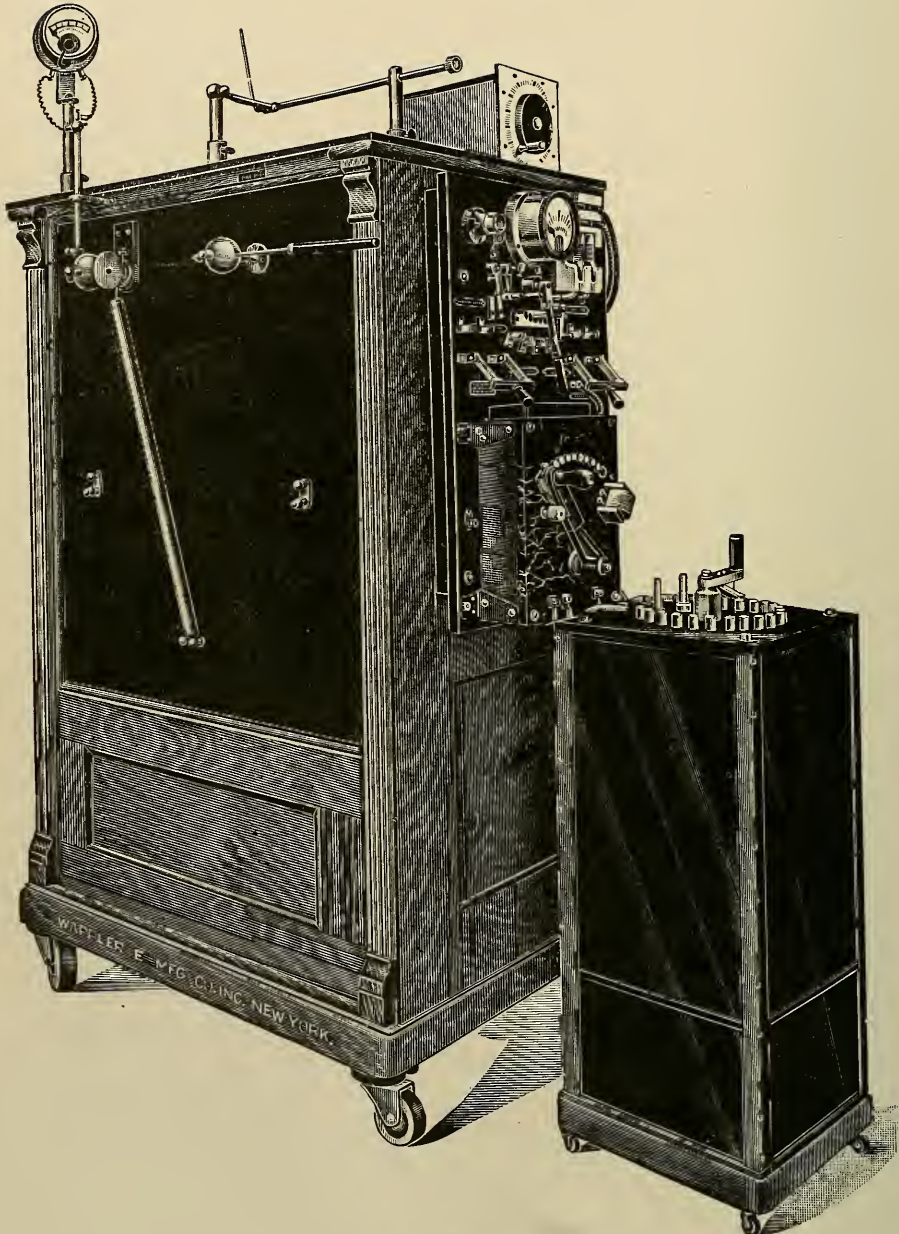


Figure 8—(see page 62)

If the direct current is the source of supply, then a rotary converter is used to produce an alternating current from the direct current. The motor set consists of a rotary converter on the direct lighting circuit, either 220 or 110 volts. The rotary converter changes the direct current into an alternating and passes it through the necessary switch, on the switchboard, and the rheostat to the transformer. On the end of the shaft of the motor is attached a round micanite disk. The low potential alternating current collected from the converter side is passed through the primary of the transformer which increases its potential to about 100,000 volts at a primary current of from 25 to 50 amperes, depending on voltage used. The high potential alternating current is then conducted from the transformer to a rotary polechanger, mounted on the armature shaft of the converter.

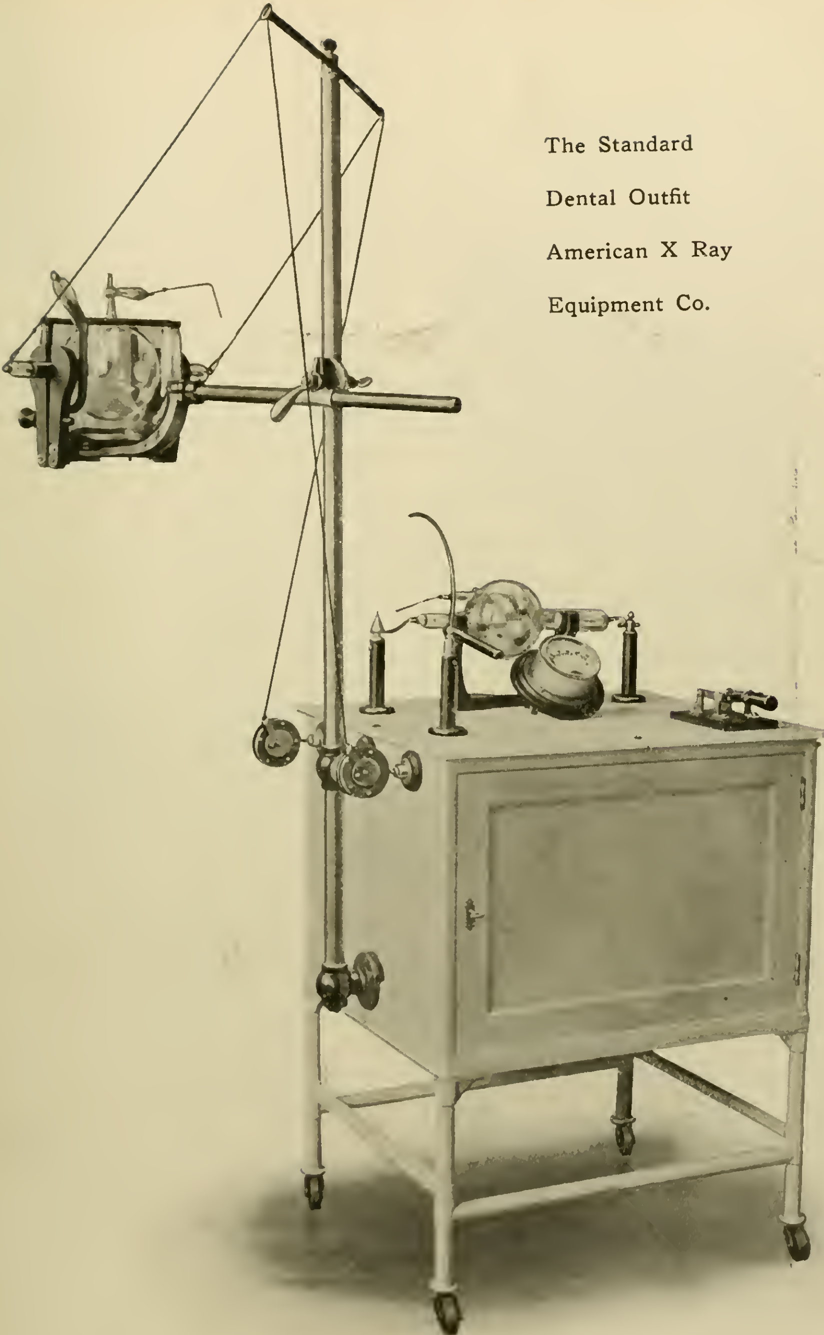
The rotary polechanger consists of a round micanite disk. To the periphery of this disk are fastened two copper strips, opposite each other, and occupying a little more than a quarter of the circumference. Parallel to this disk is a glass plate, on which are mounted four contact brushes equidistantly apart. They are arranged to commutate, or rectify the current from a high tension alternating, to a high tension, interrupted unidirectional current. The alternating current enters, as it were, at two opposite contacts, and the rectified current is taken from the two remaining contacts and conducted to the outlet terminals.

The great efficiency and superiority of this type of apparatus lie not in its high potential, which is less than some of the larger types of coils, but is due to the great increase of current strength, or milliamperage, together with the fact that the current derived is unidirectional, thus cutting out all 'inverse' in the tube. These outfits are very expensive and their use is adapted to the needs of the specialist who intends to take up general radiology as a profession, and practice it in all its varied fields and applications. To the specialist, therefore, the interrupterless type is not an extravagance, but is really a

necessity. Figure 8 represents the "King model" type of interrupterless outfit, manufactured by the Wappler Elec. Mfg. Co. of New York City. It is without doubt the "last word" in X Ray outfits.

The next type of apparatus, the induction coil, is, on the whole, used more than any other type of apparatus. It is much less costly than the 'interrupterless' and fulfils the need of the average practitioner, in fact many specialists do all their work with a good-sized coil. In its latest form it is admirably suited to the dental surgeon, and is more appropriate for his use than the larger and more expensive interrupterless kind. Figure 9 illustrates the very latest type of X Ray coil, designed especially for dental work. With it, any dentist can well compete with the specialist and his interrupterless outfit. It is not only thoroughly efficient, but is much lower in cost than any other types of coil, and occupies the minimum of floor space in the dental office. It presents a truly scientific and aseptic-looking piece of apparatus. It is made by the American X Ray Equipment Co. of New York City. For the present we will pass over the description of the induction coil and consider the other two types.

The third type of apparatus is the static machine, the use of which is becoming more obsolete every day. It is the only one of the four methods of generating the current for the X Ray tube in which the current is generated directly from friction and not stepped up from a low potential current as in the cases of the other three. In the static machine we have large wheels of glass revolving with metallic disks fastened to their surface at various intervals. These disks revolve against wire brushes and by means of the friction that is developed and the great speed with which they are revolving, generate frictional electricity. This electrical current is picked up and magnified by each revolution until it is delivered from condensing leyden jars, to the terminals of the apparatus as a high potential static current. Small static machines are of very little value to the radiologist, and the larger ones are



The Standard

Dental Outfit

American X Ray

Equipment Co.

Figure 9—(see page 62)

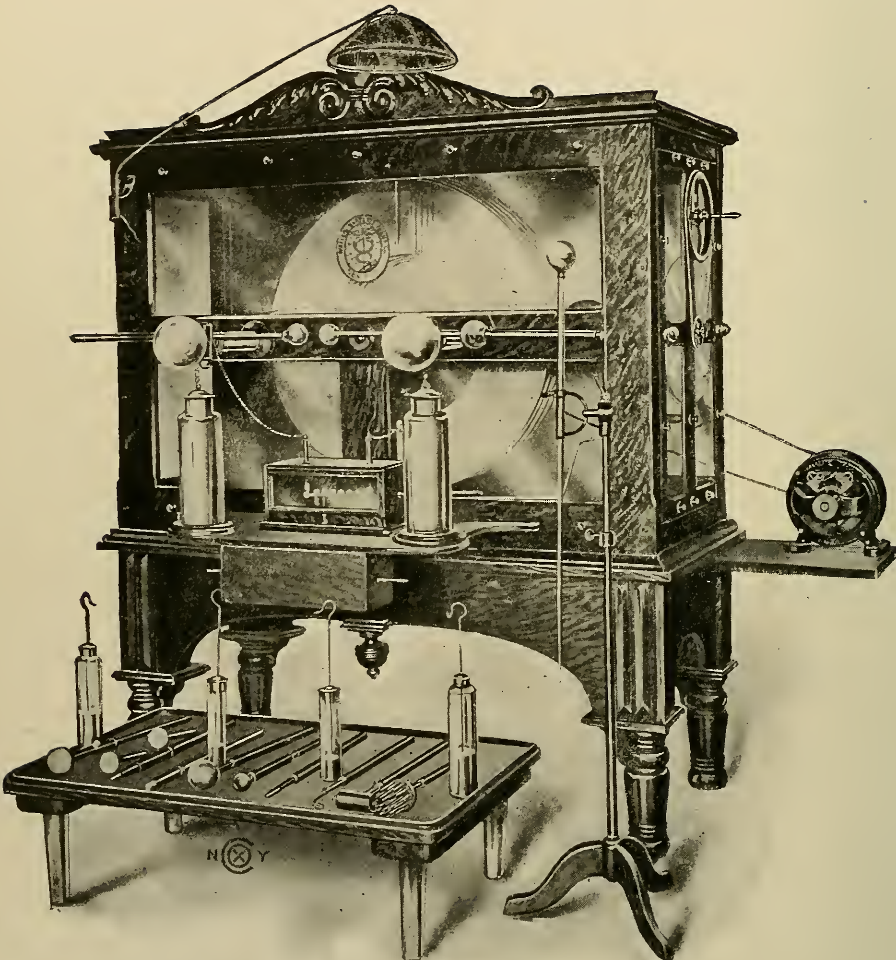


Figure 10—(see page 65)

very expensive, even more expensive than the highest type of interrupterless apparatus and with an efficiency proportionately less. Figure 10 represents the latest and most improved model of static machine, made by Waite & Bartlett Co. of New York City.

The last type, the Tesla transformer, is at the present time less efficient than the other three types, but it has one advantage of being the most portable, a complete Tesla coil that will generate a high potential current sufficient to taking a radiograph, can be carried readily in a dress-suit case and weighs only about twenty or thirty pounds. Such a piece of apparatus will give us a radiograph in from thirty seconds to a minute, a rather long time for the patient to remain still, but not impossible. It is less expensive than any of the others, and is to be recommended to those men who desire to get an outfit for as small amount of money that will enable them to do some X Ray work as an adjunct to their profession. It is a good starter for the man with the small purse and probably will be the forerunner of larger and more elaborate apparatus.

A very complete and compact Tesla type of dental outfit is being placed on the market as this book goes to press, and from tests made with it bids fair to being a very efficient model of a low-priced outfit; it is also made by the American X Ray Equipment Co. of New York City.

We will now go back to the induction coil, its principles and construction, and methods of generating the high potential current.

The current that we use in X Ray work is a high potential current, and by *potential* we mean electro-motive force or voltage. We *must* have a current of high voltage. If we attach our X Ray tube directly to the street current service wires, or to the wires from a battery we would have no result. The current would not pass through the tube. The reason for this is that the vacuum offers too great a resistance; to a low potential current the vacuum is an absolute non-conductor. Therefore a current that we can force through an X Ray tube

must be of at least 50,000 volts. Let us see how we generate this current in an induction coil.

An induction coil consists of two principal parts, each one a separate coil of wire. The first coil has but a few turns of very coarse wire (for an X Ray coil it must be of 8, 10, 12 or 14 gage wire), wrapped around a bundle of soft iron wire which forms the magnetic core of the coil. This first coil is called the 'primary' coil. The second coil is called the 'secondary' coil, and consists of a great many turns of very fine wire (usually number thirty-four silk-insulated wire is used in the secondary).

Before taking up the physics of the induction coil let us first review some of the elementary principles of electricity, that we may have a clearer understanding of the operation of the coil.

What is electricity? We do not know absolutely; we do know, however, that it is a form of energy that is invisible. At one time it was believed to be a liquid that was invisible, and that it permeated all substances, for the reason that its action followed so closely the laws of liquids. Therefore we very often use similes in hydrostatics (the laws of liquids at rest) and hydrodynamics (the laws of liquids in motion), to explain the phenomena occurring in electrical science. Even though the exact nature of this invisible force or form of energy, which we call electricity, is unknown, we are able to measure it. Instruments have been devised that will tell us just how much of this force, and to what extent it is being used. It was necessary before we could do this, to originate certain units of measurement, just as we have units of measurement for weight, for time, and for volume.

The first unit of measurement is the *'volt'* which may be defined as *the unit of electro-motive force.* This tells us very little until we know what electro-motive force is, and to explain that we will consider a simple simile:—

Suppose a tank of water is situated upon the roof of a tall building. From this tank of water we have a pipe leading

down to the ground floor, which can be tapped at all the intermediate floors to furnish the people in the house with water. At the ground floor there is a greater pressure than at the top floor; the tenants at the top of the house do not get as great a force of water as those living on the first floor, because of the weight of the water in the pipe, together with the laws of falling bodies, which materially adds to the pressure, or the head of water, at the lower level. This water pressure is analogous to voltage in an electrical current.

The unit of measurement of electro-motive force means the unit of pressure. It is the amount of electricity measured in its potential, its power, its intensity or tension. In the case of the tank, the higher the tank is from the street the greater will be the potential, or the greater will be the force; and that force may be likened to the power that sets electricity in motion.

Now suppose we have two pipes coming down from this tank, one a half inch in diameter and the other one two inches in diameter. Which will discharge the most water? The two-inch pipe you will say discharges more water. That is true, but it does not come with as great a force from the two-inch pipe as it does from the half-inch pipe. You have probably noticed that with a garden hose, if you press the nozzle together, you can throw the water to a greater distance. You have increased the pressure. This pressure is analogous to voltage in an electrical current.

The quantity of water passing through the pipe in a given time, that is, the number of gallons per hour, is analogous to the second unit of measure for electrical currents, called the *'ampere.'* The definition of the ampere is, *the unit of current-strength;* in other words, it is the amount of current passing a given point on a conductor in a given time. You see, therefore, the difference between volts and amperes. The volt represents the intensity of the current, and the ampere represents the rate of current-flow. One only exists at the expense of the other. Just as we have pressure and quantity in water, if we increase the pressure in the garden hose, we throw the

water a greater distance, but we do not deliver as much water in the same time. If we increase the diameter of the pipe and allow more water to pass it is not thrown to as great a distance; the pressure is less. One, therefore, exists at the expense of the other.

The third unit of measurement that we have to consider, is the unit of resistance called the *'ohm.'* It would be analogous in our water pipe to the number of curves and bends and to the friction of the water against the side. It is the resistance that the column of water has to meet with, and in electrical currents it is the resistance of a poor conductor which absorbs some of the electricity and converts it into another form of energy which we know as heat. If it were not for resistance we would have no incandescence in electric lamps. The ohm is the actual resistance offered to an electrical current by 150 feet of copper wire, one millimeter in diameter, or it is the resistance offered by a column of mercury one meter in height and with a diameter of one millimeter.

We have considered the three practical units of electrical measurement, viz., the volt, the ampere and the ohm. The volt or the unit of electro-motive force, the ampere, the unit of current strength, and the ohm, the unit of resistance. One of the fundamental laws upon which all electrical science is based is known as Ohm's Law. The formula is this:

C equals E divided by R. $(C=\frac{E}{R}.)$

In this formula C stands for current or amperes; E stands for electro-motive force or volts; R stands for resistance or ohms, so that we may write that same law in another way: Amperes equal volts divided by ohms.

From this law, which is in the form of an equation, we can find any unit provided we have the other two units given; for example, we will take a simple problem: How many amperes will pass through an electrical lamp operating under a potential of 110 volts and with a resistance of 220 ohms?

Applying the formula, it will read this way: X equals 110 divided by 220. X being the amperes that we wish to find, 110 representing the voltage passing through the lamp and 220 representing the ohms of resistance to that current. Reducing this fraction to its lowest terms, we see that it equals ½; therefore, we have ½ an ampere of current. By transposing Ohm's Law formula we have

$$E=R\times C, \text{ and } R=\frac{E}{C}$$

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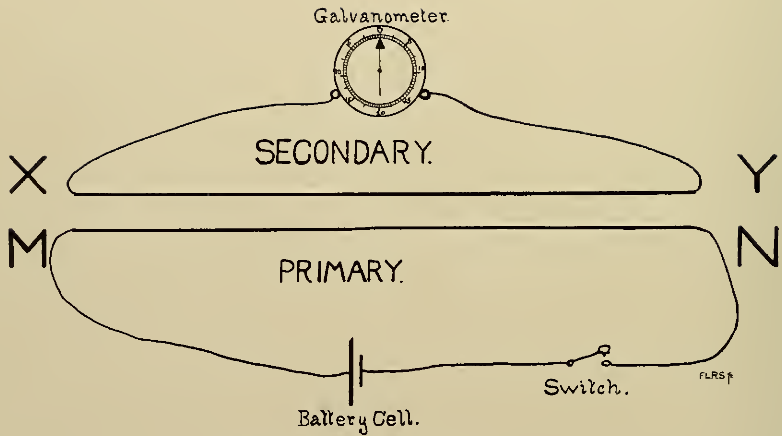

Figure 11 —(see page 73)

CHAPTER IX.

Electrical Induction—Construction of X Ray Coils

Let MN (in Figure 11) represent a straight wire connected at both ends with a battery, and let XY also represent another wire that is near to and parallel with the first wire, and connected at both ends to a galvanometer. We have, therefore, two separate and distinct circuits, the first made up of the wire MN, the battery B and the switch S, which we will call the '*primary*' circuit. The other circuit consisting of the wire XY, which is of equal length and thickness as MN and the galvanometer G, which will record the presence and comparative intensity of electrical impulses.

We will now "make" the primary circuit, in other words, close the switch and allow a current of electricity to pass through the wire MN. At the instant that the current passes through the wire MN, a single impulse is generated in the secondary circuit, or the wire XY, which lasts but for a single instant, as shown by the deflection of the galvanometer needle, we will say, two points to the right and its immediate return to 'O.' There is no more current passing through XY, although the current continues to pass through MN. When we "break" the current that is passing through MN (open the switch) and cause it to stop flowing, we will have another current generated in XY, but flowing in the opposite direction, as shown by the galvanometer needle deflecting two points to the left. This also will be but an instantaneous impulse and then it will stop. This phenomenon is known as *induction* and always takes place where we have a conductor in the neighborhood of another conductor, and when there is a current of electricity passing through the former. Induction takes place at its maximum, or

we say the inductiveness is at its maximum when the neighboring conductor is parallel with the original conductor. If the neighboring conductor was at right angles to the one that the current was passing through, we would have no impulse, and it would vary from nothing to maximum as we swing the angle round through the quadrant of 90 degrees. The same phenomenon takes place in the induction coil. We pass a current of electricity through the primary coil and a current is induced in the secondary coil, the layers of which are parallel to each other. There is no connection between the two coils. They are both separate and distinct, yet a current is induced in the secondary coil when the current in the primary is started and when it is stopped. If the windings of the primary consisted of but a single layer with a given number of turns and the windings of the secondary consisted also of but a single layer, with the same number of turns, the potential of the secondary would be the same as the primary, the voltage *would not be increased,* but if we *increase* the number of turns in the secondary we get an *increase of potential* which is caused by the phenomenon of *self-induction;* in other words, each turn of the secondary induces a current in the turn directly adjacent which must be added to the induction that is caused from the primary current, so that in the first layer of the secondary, if it had ten times the number of turns, the potential would be ten times as high as the primary; in the next layer it is the same as the first layer, plus the extra induction of the current flowing through the additional number of turns in the second layer of the secondary; in the third layer it is still higher, because the effects of the first two layers are added to the effect of the primary, and so on, through all the layers of the secondary coil. If we consider the number of layers and the number of turns that the secondary wire takes in the length of about twenty-eight miles (which is about the length of the secondary of a 12-inch induction coil) you can readily see that we are adding an enormous quantity of potential to the original current flowing through the primary coil.

As the voltage was increasing the amperage was decreasing with an equal ratio. The wire was very fine in the secondary, offering great resistance to the passage of the electrical current; consequently the rate of flow or amperage must be decreased as the potential increases, so that the output from the secondary coil would be perhaps 120,000 volts and about ten one-thousandths of one ampere, or 10 milliamperes. If we compare the original current in the primary of 110 volts (and we will say 30 amperes), we will see that nothing is changed in value, only the form of the current has been transformed. It is the same case as though you took a ten-dollar bill to the bank and exchanged it for ten one-dollar bills. We have no more value than we had before, but we have it in a different form, so that it can do a certain class of work which we wish it to perform, where the other one would not. We have not *created* any new energy.

The following table shows six manipulations of the primary circuit that give us impulses in the secondary. Let us carefully examine the table.

TABLE OF PRIMARY MANIPULATIONS GIVING SECONDARY EFFECTS

SECONDARY EFFECTS	
INVERSE — to +	DIRECT + to —
PRIMARY MANIPULATIONS	
—2 Make	+2 Break.
—1 Approached	+1 Withdrawn.
—4 Increase of potential.	+4 Decrease of potential.

Under the heading, 'secondary effects,' we will see the words inverse and direct; inverse meaning a current flowing from negative to positive, and direct, a current flowing from positive to negative. In the two columns below we will find the manipulations of the primary coil that give us these effects in

the secondary; in other words, the causes for these effects. There are six causes altogether, or *six manipulations of the primary that give us effects in the secondary.* The first two are 'make' and 'break.' We will find in the first column 'make' and in the next column 'break.' This means that if you 'make' the primary, or start the current flowing, you get a single impulse in the secondary which is 'inverse' in direction. When you 'break' the primary you get a single impulse in the secondary that is 'direct' in direction. The next two manipulations of the primary are the 'approached' and 'withdrawn' currents. We see in the first column 'approached' and in the second column 'withdrawn.' In order to explain the meaning of the 'approached' and 'withdrawn' currents, we will have to suppose that we have a small induction coil, operating with a battery and not from the street current, and having a primary that is removable; that is, the primary coil may be drawn out from the core where it rests inside the secondary. We will 'make' the current in the primary. We get a single impulse in the secondary and then there is no more current flowing. The secondary circuit for the time being is 'dead,' *although the current continues to flow in the primary.* Now if we take hold of the primary coil and suddenly *pull it out from the core,* where it rests in the secondary, we get an impulse in the secondary circuit *just as though we 'broke'* the primary current. Again quickly replacing the primary back into the secondary, we get another impulse which is 'inverse' in the secondary. The 'approached' and 'withdrawn' currents are obtained, therefore, by altering the relative distances between the primary and the secondary coils, either *approaching* the primary *to* the secondary or the *removing* of the primary *from* the secondary. The next two ways of obtaining impulses in the secondary are by the 'increase' and 'decrease of potential.' In the first column we find 'increase of potential,' and in the second column 'decrease of potential.' We mean by 'increase' and 'decrease of potential' the *increasing of the voltage* and the *decreasing of the voltage of the primary circuit.* Suppose, in the small induction coil

that we just referred to, that we had a switch by means of which we could throw in the current from six dry cells in addition to a battery of ten, which we had originally. We first 'make' the current with the battery of ten dry cells. We get one impulse in the secondary at the 'make.' Now with the current still flowing in the primary with a potential of 10 volts (each dry cell giving approximately 1 volt), we throw in, *without breaking the circuit,* an additional supply of voltage from the six extra dry batteries. We therefore have an 'increase of potential' in the primary circuit. The voltage is raised from 10 to 16. At the instant that this takes place we have an impulse in the secondary which is 'inverse' in direction. Again, if we were suddenly to *cut out* six dry cells we would decrease this voltage from 16 to 10, and we would get an impulse which would be 'direct.' These are the six methods of obtaining impulses in the secondary, and they are the *only* ways by which we can get secondary impulses; but they are not all equal to each other.

Let us suppose that we have an induction coil *without any internal resistance* (which is impossible, although coils may be constructed coming pretty close to it), also let us suppose we have a sensitive galvanometer in the secondary circuit. We will 'make' the primary, and show the impulse passing in the secondary by a deflection on the galvanometer. We will suppose that it deflects two points to the left. We will put down, therefore, opposite the word "make" the figure 2, and since it gives us the inverse discharge, we will mark it minus (—). When we 'break' the current we would get a deflection in the galvanometer of *two points on the other side,* provided, of course, the coil was without resistance; the needle having come back to zero would swing over to two points on the right side and register the single impulse and then comes back again to zero. We will put down opposite the word "break" this figure 2, with the plus (+) sign before it, because it represents a direct current flowing in the secondary. In the case of the approached and withdrawn current the galvanometer might

show only a deflection of one volt. We therefore put down the value, one, in both columns, with the minus (—) on one side and the plus (+) on the other. That means that the impulse of the 'approached' and the 'withdrawn' was only, *in this case,* one-half as great as the impulse of the 'make' and the 'break.' Now the impulse of the 'increase of potential' and 'decrease of potential' may be twice as great as the 'make' and the 'break,' depending on the *amount* of 'increase' and 'decrease;' therefore, the galvanometer would show, we will say, in this case a deflection of four points to the left and to the right, according as we 'increase' and 'decrease the potential.' We will put down, therefore, a value of minus (—) 4 for the 'increase of potential' and a value of plus (+) 4 for the 'decrease of potential.' Now, therefore, we have in this case a ratio of 'one is to two is to four.' This ratio is *not always constant,* but depends on several controlling factors; neither de we *ever, in practice,* have the inverse impulses equal to the direct impulses. They are always greater.

The current that we use in the X Ray tube, that is, the high potential secondary current, entered the tube at the *negative* or the *cathode side;* it passed through the tube and out again at the anode or the positive side of the tube. This was, consequently, what we term an 'inverse current' flowing from negative to positive. This 'inverse current' is obtained from the secondary of the induction coil at the *'break' of the 'primary,'* and yet by looking at the table we see that the 'break' of the primary should give us a 'direct' current in the secondary. This apparent discrepancy takes place because we have two factors taking place at identically the same instant. *At the instant that we get our 'break' in the primary, we also get an 'increase of potential'* (produced automatically in the interrupter, which we will consider later), both taking place absolutely simultaneously. We have, therefore, the effect of a plus value, which was that of the 'break,' and the effect of minus value, which was that of the 'increase of potential,' to be added. This latter value *always exceeding* the former, and

in the case of large X Ray coils and electrolytic interrupters the intensity of the 'increase of potential' effect is sometimes twenty or thirty times as great as the 'make' and 'break' effects. The result being a predominance of the effect of the 'increase of potential' over that of the 'break,' giving us as a result an increased potential current, *'inverse' in direction, at the instant of the 'break.'* The 'increase of potential' had a greater effect on the secondary than the 'break,' but as they were opposite effects the stronger is going to predominate over the weaker.

In the construction of an induction coil for X Ray work we must have a 'primary' that is removable from the 'secondary.' This, because it may be necessary to make a repair on the 'primary,' due to the short circuiting of the current. It would be inconvenient to unwind a great many miles of wire in order to get at the 'primary' to make a repair, and it is therefore easier to construct the coil originally so that the 'primary' may be removed. Another requisite of a good coil for X Ray work is a *thoroughly insulated 'secondary.'* This is obtained by winding the secondary coil in two or more segments. The segments are insulated from each other and all boiled separately in a composition wax. Afterward, when they are placed in the case that will enclose them, and their terminals joined, the entire case, which is to form the finished coil, is filled with the same melted wax composite. This is the best form of insulation. If a current should jump from one layer to the other in the 'secondary,' caused by a 'breakdown' of the silk insulation, the wax in contact would also be melted by the heat generated, the melted wax would flow over the bad part of the wire and would reinsulate it. These are the two principal features of the construction of the coil.

An X Ray coil has no vibrating interrupter attached to it *as part of the apparatus.* In X Ray work the interrupter forms a separate and distinct piece of apparatus, the 'coil' itself consisting of nothing but the 'primary' and the 'secondary' coils, the core and the terminals.

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Electrolytic Interrupter.

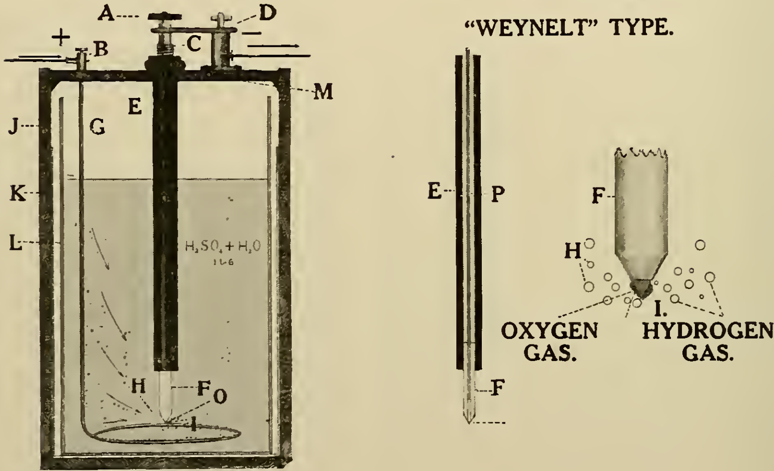

Figure 12—(see page 83)

CHAPTER X.

The Interrupter—Tube Shields—Valve Tubes—Wiring Diagrams

It is necessary in order to obtain a practically continuous current in the 'secondary' coil to have some means for automatically 'making' and 'breaking' the current in the 'primary.' We cannot do this with sufficient rapidity by means of the hand, so we have to utilize some automatic principle. The instrument, by means of which we obtain these interruptions, is called an '*interrupter*.'

There are two classes of interrupters, mechanical and electrolytic. There are a great many forms of mechanical interrupters, the simplest of which is the ordinary vibrator that we see on most of the small medical coils and buzzer bells. Their operation all depend upon some mechanical principle, and as there are so many of them we have not the space to consider the subject in detail. We will pass on, therefore, to the description of the electrolytic interrupter.

There are several forms of electrolytic interrupters, although they all depend on nearly the same principle. We will describe, therefore, the 'Weynelt' type of electrolytic interrupters. The construction is as follows: We have a large battery jar L (Figure 12), which is nearly filled with a solution of sulphuric acid and water; one part of sulphuric acid to six parts of water. The purpose of the acid in this solution is only to make the water a better conductor; water in itself is not a good conductor of electricity, but when it is acidulated the conducting power is very much increased. Into this acid solution we introduce two electrodes, a positive and a negative. The positive has a large extent of surface, while the negative has a very small extent of surface. These are the two principal features of the apparatus. The one shown in

the illustration G represents the positive electrode as a loop of lead wire. The reason why we use the metal lead is because it will not be affected by the dilute sulphuric acid.

The negative electrode EFI is more complicated. It consists first of the insulated portion E, which is a tube of hard rubber of vulcanite, from which projects a small porcelain tube F. Through this porcelain tube and hard rubber tube we pass a lead wire P with a platinum point I, the *tip* of which only extends below the porcelain tube. This is the only part of the negative electrode that is exposed to the action of the electrical current. By means of the set screw AC, at the top, we can raise or lower our lead wire with the platinum tip, so that a greater or smaller amount of the platinum extends below the porcelain tube.

When we pass a current of electricity through a liquid that has two electrodes immersed in it, we have the phenomenon of electrolysis taking place. The water of the solution is decomposed into its hydrogen and oxygen elements. Hydrogen gas, therefore, is formed all over the surface of the positive electrode, but these bubbles of gas, H, do not remain upon the positive electrode; they take the path of the current through the liquid and are deposited upon the negative electrode I. The oxygen bubbles, O, are formed on the surface of the negative and remain there because they cannot flow against the action of the current, the result of which is that we have an accumulation of the two gases, hydrogen and oxygen, at the negative electrode. In the case of the Weynelt Interrupter the positive electrode has a great extent of surface, while the negative electrode is confined to a very small platinum tip, which projects below the porcelain tube, and the bubbles of hydrogen, which were formed all over the surface of the positive electrode, passed through the solution and were deposited around the tip of the platinum point, therefore mixing with the oxygen gas, in the proportions of two parts of hydrogen to one of oxygen. This film of gas completely surrounds the exposed tip of the negative electrode, and acts as a non-conductor to the

current. Since two things cannot occupy the same space at the same time, the solution and the gas cannot both be in contact with the negative point at the same instant. Therefore, when the gas is in contact the liquid is not; but the liquid was the conductor of the current; therefore, if the liquid is not in contact there *is no current flowing*. The circuit of the current is broken. An electrical current passing from a large extent of surface to a small extent of surface will generate heat by resistance. The tip of the negative electrode becomes so hot that it glows with a white heat, therefore, we construct the tip of that electrode of platinum, which metal has a high fusing point. The mixture of hydrogen and oxygen gases form an explosive compound. The heat developed in the negative electrode is sufficiently great to ignite this explosive mixture, and we have an explosion. The chemical result of the explosion is the formation of water, which once more mixes with the solution, which again comes in contact with the electrode. The current is once more established, causing the 'make' of the circuit. Immediately the bubbles will again form, producing another 'break,' followed in quick succession by the explosion which again 'makes' the current, and so on, with great rapidity.

With the Weynelt Interrupter it is possible to obtain 250 breaks per second, and this rate of interruption may be varied by the turning of the set screw at the top, which adjusts the amount of platinum point extending beyond the porcelain tube into the solution. The greater the quantity of platinum exposed, the longer it will take for the bubbles to form, and the longer it will take for the surface to become heated; therefore, the less frequent the interruptions. When we draw up the platinum point and allow a smaller extent to protrude, we increase the rate of interruptions. Almost all electrolytic interrupters are constructed on similar lines and depend practically on the same explanation for their operation.

We have seen from this description how we obtain our make and break. Let us now consider how we get our increase of potential at the instant of the break, that we discussed under

the theory of the induction coil. Let us go back to our old simile of the tank of water on the roof. Suppose we have a pipe discharging water *into* the tank. We will also assume that we have another pipe *leading out* from the tank which has exactly the same diameter of opening. You will see, of course, that the water will remain a constant height in the tank. It flows out just as rapidly as it flows in. We will also place a stopcock on the lower pipe, or the one leading out from the tank. If we gradually turn this stopcock closed, what will result? The height of the water will rise in the tank, and the amount of water coming out will decrease, but the potential, or the strength of that current, will increase. What have we done? We have raised the head of pressure (analogous to voltage) and we have decreased the rate of flow (analogous to amperage). At the instant that the stopcock closes off the supply of water the pressure has reached its maximum potential. This principle is exactly what takes place in the interrupter. A bubble of gas forms on the platinum point; then another bubble; then another, and so on, one after another, each one reducing the surface of the electrode that is exposed to the action of the electrical current, just as though we were turning the stopcock closed in the tank. We finally reach a point where all the bubbles have formed that can cover the surface of the electrode, with the exception of the last one, which will close the circuit. The potential has increased bubble by bubble to this point as its maximum. As the last bubble forms which breaks the current, the potential of the current coming from the positive has reached its maximum. The 'break' and the maximum 'increase of potential' taking place at the same identical instant.

We have described three of the four essential parts of the apparatus, namely, the X Ray tube, the Induction Coil and the Interrupter. The fourth is the X Ray Tube Shield. This last piece of apparatus is absolutely essential, not to the working of the apparatus, but to the protection of the operator. There are different means of protection. Some operators prefer to cover

their own persons with a substance that is opaque to the X Ray, as, for example, a suit of lead armor, thus protecting their body from exposure to the X Rays. This method is not a good one. You will readily appreciate the discomfort of the operator carrying about with him a heavy suit of lead, and you may rest assured that the instant that he is through with the taking of a picture and has turned his current off, he will immediately strip himself of his lead suit. He forgets that the *secondary rays,* that are given off by every object in the room that has absorbed the primary rays, *are still active in the room,** and he therefore submits himself to the secondary radiation, which in time may produce even more serious results than those of the primary radiations. Another method that is sometimes employed for the protection of the operator, is a large screen which is lined on one side with sheet lead or other substance, opaque to the X Ray. This screen having a window made of lead-glass at about the height of the operator's eyes. When his apparatus is in action he goes behind the screen, and observes the working of the tube by watching it through the lead-glass window. Again, when he turns off the current, he steps out boldly from behind the screen and walks up the tube, *forgetting again the secondary rays.* For dental work this method of protection, as well as the first, are not only *inadequate,* but they are really dangerous to use. The best method of protection is not the shielding of the patient or the operator *directly,* but to place a box lined with some material opaque to the X Ray, such as a lead-glass shield *around the tube itself,* thereby confining all rays, *both primary and secondary,* to the inside of this box or shield. This device is called a Tube Shield. They are made in many different forms, but their requisite is that they be absolutely opaque to the X Ray, and that they do not conduct an electrical current. You will see, therefore, that it is impossible to line this box with metallic lead, which would otherwise be the best substance that we could obtain, for the reason that

* The author has made an actual radiograph with the secondary emanations from objects in the laboratory that have received direct X Ray exposure.

the electrical current instead of passing through the tube, which has a high resistance, would, in preference, jump to the metallic lead lining and would pass through that as the path of least resistance. There are several substances that have been used with more or less success in the linings of these shields, all of which are non-conductors of electricity. One of the best mixtures is that of red oxide of lead, subnitrate of bismuth, a little glue and plaster of paris. This mixture, when soft, is laid in a layer of about a quarter of an inch thick all over the insides of the box and after it has set and hardened, is painted with a lead paint. The opacity of this substance for the X Ray is very great. There are other forms, such as rubber that has been impregnated with lead salts, that also serve as good protection, but it is decidedly necessary for the operator before he starts work to secure for himself a shield that gives really good protection. An excellent shield is constructed of glass impregnated with lead salts, not affecting its transparency, but rendering it proof to all X Rays, except those more penetrating ones obtained from very high vacuum tubes. These rays, however, have hardly any dermatological effects. The opacity may be tested by the placing of a film and an interposed coin, on the outside of the shield and operating the tube for a short time and then developing your film, thereby determining whether it received any exposure to the X Ray or not. If the shield is not safe a shadow of the coin will be seen on the negative. Of course the shield must have an opening through which the rays can escape and reach the patient. Tube shields are usually made with different size openings. If constructed of a material opaque to ordinary light, it is well to have a window of lead-glass, so that the working of the tube and its coloration may be observed by the operator. If one stands out of the path of the ray as it emerges from the opening in a really good shield, he is absolutely safe from all exposure to the ray, and when the current is turned off he may rest assured that whatever ray was given off was confined to the tube shield, except the small amount that passed through the opening, most of

which was absorbed by the patient and carried away to be given off later as secondary radiation *outside his office.*

When an induction coil is used to generate the high potential current, the 'secondary' output is necessarily an alternating current, since the impulses of 'make' and 'break' are in opposite directions. As we use only the stronger 'break' current in the X Ray tube, the weaker current of 'make' must be cut out of the tube circuit. This can only be done by introducing sufficient resistance in the 'secondary' circuit to prevent the weaker current of 'make' from passing, but allowing the stronger 'break' current to complete its circuit.

In a low potential circuit we would use a resistance coil or rheostat to attain this result, but currents of high voltage cannot be controlled by wire resistances; therefore we must resort to the use of vacuum and air gaps to sufficiently check the high potential impulses of 'make.'

The best method for preventing the 'make' current from passing through the X Ray tube is to employ another or auxiliary vacuum tube in the 'secondary' circuit. This tube is called a valve tube. It is constructed on the same principles as the main X Ray tube, but has a funnel-shaped anode made of aluminum, instead of the platinum disk of 45 degrees. This anode reflects the bi-ultra violet rays directly back upon the approaching rays, thus retarding them and reducing their force of impact against the anode. As the bi-ultra violet rays do not impinge upon the anode with as great a force as they do in the X Ray tube, they are not transformed into tri-ultra violet. No X Rays being formed, therefore, in the valve tube, it is not necessary to inclose this tube in a shield. The vacuum of these tubes is lower than in the main tubes.

Air gaps, called spark-gaps, are also employed in some circuits to further cut off the 'make' current from passing through the tube. They are often made adjustable. This objectionable current of 'make' in the X Ray tube is frequently referred to as "inverse current."

AN INDUCTION COIL INSTALLATION

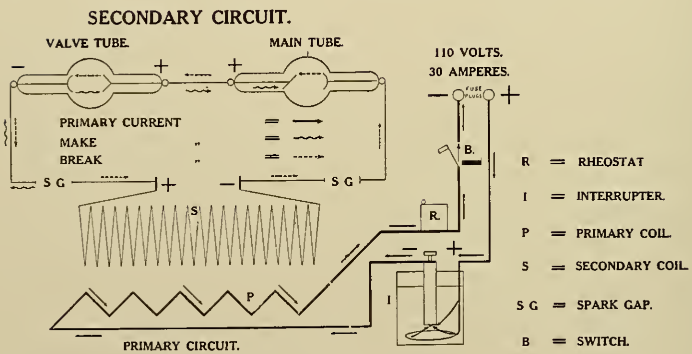

Figure 13—(see page 91)

Figure 13 represents a complete wiring diagram for an induction coil installation. We will first trace out the path of the 'primary' current indicated by the straight arrows. It comes from the 'cutout' on the commercial circuit supply wires as a direct current of 110 volts, and we will say about 30 amperes. It enters the interrupter by its positive electrode of lead wire, passes through this, and flows through the primary coil of the induction coil as an interrupted current. In the diagram the 'primary' coil is represented by the short-waved line, P, shown as situated outside of the 'secondary.' It must be borne in mind that this is only a diagrammatic method of representing it. In reality, the 'primary' has two or more windings and fits snugly inside of the 'secondary.' From the 'primary' coil the current flows through a rheostat, R, and the switch, B, and so back to the negative side of the service 'cutout.'

It is not absolutely necessary to include a rheostat, or adjustable 'resistance box' in the 'primary' circuit. We do not find that there is much necessity for the reducing of the primary potential in dental radiography, other than when regulating the vacuum of the tube. Therefore, in some of the best outfits for dental work, there is in place of the adjustable rheostat, a fixed resistance coil which can be introduced into the circuit by a special switch.

The switch, B, is to turn on and off the primary circuit in making the exposure. This switch, the rheostat or fixed resistance coil, the primary coil, and the interrupter, are all in series with each other, consequently it makes no difference as to their relative arrangement. The grouping of them, as shown in the diagram, is purely arbitrary.

In the 'secondary' circuit we will start with the current of 'break,' which is indicated by the broken arrows. It leaves the negative side of the coil, and jumps across the adjustable spark-gap, if open, thence to the cathode terminal of the main tube. It passes through the tube, leaving by the anode, enters the anode of the valve tube, passes through this, out through

the cathode of the valve tube, across the second spark-gap, and so back to the coil terminal on the positive side.

The 'make' current, if it could flow, would start out from the positive terminal of the coil, as represented in the diagram by the wavy arrows, would jump the spark-gap and enter the valve tube by the cathode terminal. Passing through this vacuum, it would enter the main tube and flow as far as the surface of the anode. Here it would meet with the second vacuum gap that must be overcome. The potential, being lower than that of the 'break' current, is not sufficient to break down this added resistance; consequently *it should not flow at all.* In practice, however, some 'make' or 'inverse' tube-current does complete the entire circuit, even the second spark-gap. The small amount, however, that does pass the resistances can do but little harm in the actual working of the tube and the resulting picture. The lower the vacuums of the two tubes the more apt the 'make' current is to pass.

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CHAPTER XI.

The Film and Its Preparation

Radiographs of the various parts of the body are made with especially prepared photographic plates, called "X Ray plates." In dental work, however, it becomes necessary to take pictures inside the oral cavity. Glass plates are not suitable for this class of work. We therefore employ small cut films that have been especially prepared for the purpose. These can be placed in the mouth and made to conform with the curvature of the palate.

The basis of these films is celluloid in thin transparent sheets. The celluloid backing is then coated with an emulsion of gelatin, that has been sensitized with certain chemicals, principally the silver bromides. This renders the film sensitive to all actinic rays, and, of course, the operation of sensitizing must be carried on under the non-actinic light of a red lamp. The exact formula with which the films are sensitized remains a trade secret of the manufacturers. There have been many different makes of films advocated for dental radiography. Some are more rapid than others, but where the speed of the film is materially increased, the contrast or gradations in 'lights and shadows' will not be so good. An ideal film, especially prepared for dental radiography, consists of the 'Eastman Dental X Ray Film.' This film has been used with entire satisfaction by the author for the last ten years. It is not a particularly rapid film, requiring fairly long exposures, but where the element of time is not essential; that is, where the type of apparatus is powerful enough to give good results in five to ten seconds' exposure, with these slower emulsion films, their use is certainly to be advocated. Recently the Eastman Company have been experimenting with several new emulsions,

to the end that they might increase the working speed. They have succeeded in turning out a film about five times as fast as their old ones. After repeated trials with the new films the author has gone back to the old ones, getting better grades of contrast with the slower emulsion. Another film that is used extensively is an English product, made by the Ilford Company of London. These films are made in several sizes and shapes. They are, by actual test, about ten times as fast as the 'old' Eastman film. Where great speed is required, as, for example, with some of the types of apparatus that give but a minimum potential, their use is to be strongly recommended.

The standard size of the dental film is 1¼ x 1⅝ inches. This is a good average size, and can conveniently be placed in the mouth. In cases of very small children, the size may be cut down by the operator.

The 'old' Eastman film is supplied in small paper packets of standard size. There are two films placed in each packet, so that two duplicate radiographs are made by the single exposure. This is a most useful and desirable practice. The films are wrapped in black paper when received; each packet being sealed by a white paster on the back, or non-sensitive film surface of the packet. The films are lightproof when received, but they are not moistureproof. They cannot be placed in the mouth as they are, as the saliva would penetrate the black paper and ruin the films inside. We must prepare these films before using, by wrapping them in thin sheets of palate rubber or other moistureproof material. The author uses an extra thin grade of palate rubber, made in two colors—the brown or pure rubber and red. The paper packets are laid *sensitive side down,* upon the *red* rubber, the cloth covering being first stripped off one side of the rubber. A sheet of the pure rubber is then placed over the packet and allowed to overlap a little, the same as with the red. On pressing the edges tightly together, by running an instrument of some kind, or the finger nail, around the outline of the film packet, the two rubber surfaces will cohere perfectly. The surplus rubber is then

trimmed off, care being taken not to cut into the paper packet. The resulting packet is quite waterproof.

Films should not, however, be wrapped in rubber for any length of time, as the sulphur in the rubber will work its way through the paper film covering and injure the films. It is not well to leave films so prepared longer than about *twelve hours* in the rubber covering. The 'new' Eastman film is furnished in an outer covering of red waxed paper. This is moistureproof in itself and needs no extra rubber wrapping. The Ilford films are wrapped in an outer coating of gutta-percha, which protects them from moisture.

Some makes of dental films have rounded corners, so that when placed in the mouth the corners will not dig into the tissues.

As a matter of fact, the number of cases where the sharp cornered film causes any real discomfort to the patient are very few, and the operator can, in those cases, go into his dark room, and with the light of his red lamp trim away the *one* offending corner, and rewrap the film. This is a better practice than rounding all the corners of all films, since we do not sacrifice any of the valuable film surface, which is really small enough as it is.

CHAPTER XII.

Application of the Principles of Shadows, to Avoid Distortion

Before proceeding with the methods of placing the film in the mouth, we will first take up a few principles that have an important bearing on this part of the subject.

"A dental radiograph might be defined as a shadowgraphic representation of the several dental tissues, taken plane by plane, and each plane superimposed on the next, from facial to lingual surface." Note particularly that the radiograph is a 'shadowgraphic' and not a 'photographic' representation of the tissues. The images that we see on a dental negative are not the actual teeth photographed on the film, but merely shadows of the actual teeth. Since, therefore, we deal only with shadows, you will readily appreciate how easily these shadows may be distorted. Wherever a shadow is cast, it must be of some object that is between the surface upon which the shadow is thrown, and a source of illumination. The source of illumination may be the sun, an arc lamp, or other light-producing medium, or it may be the radiations from an X Ray tube. The surface upon which the shadow is cast we will call the 'screen.' The relative positions of the object, the source of illumination, and the screen, determine the size of the resulting shadow. Shadows may be distorted by 'elongation' or by 'foreshortening.' The same laws apply to the shadows cast by the X Ray, as with any other source of illumination.

The closer the object is to the screen the clearer and sharper will be the resulting shadow, and the more exact in size. Hold your hand between a lamp and a sheet of white paper, as a screen, at the distance of about a foot from it, and observe the shadow cast.

SHADOWS

Fore-shortening Of Shadows.

Fig. 14

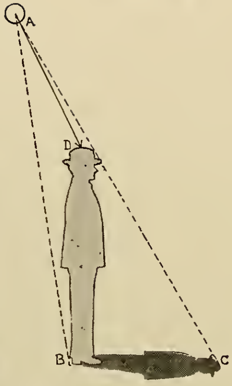


Fig. 15.

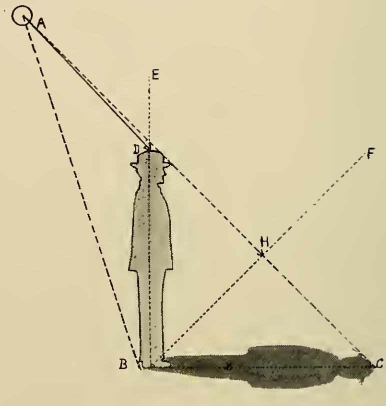


Fig. 16.

Elongation Of Shadows.

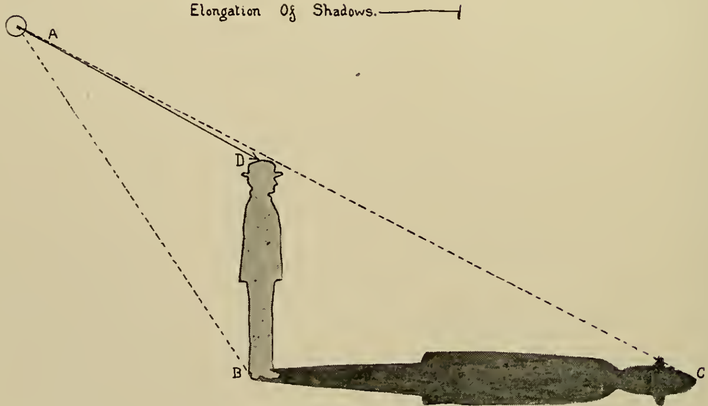


Fig. 17

You will note first that it is very much enlarged, and secondly, the outline will be faint and indistinct. Now slowly approach the screen with your hand. You will observe that the shadow becomes more distinct and smaller, till at length, when the hand is almost touching the screen, the shadow will be good and black, and of almost the exact size of the actual hand. From this experiment, we learn that in radiography the closer we get the plate or film to the tissues we wish to show, the clearer and sharper will the resulting picture be.

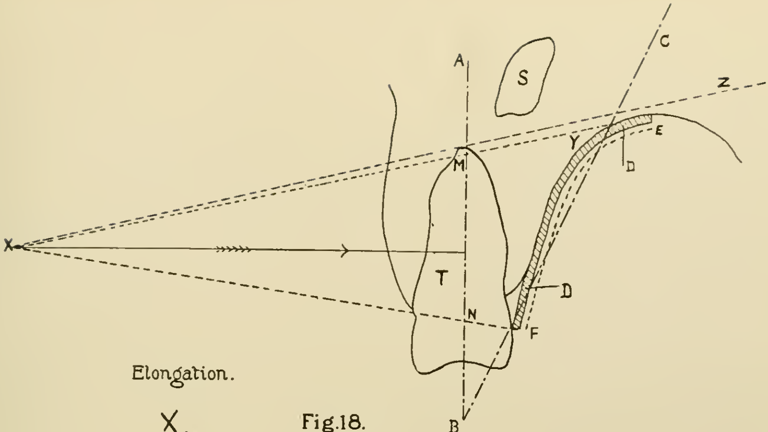
Let us refer to Figure 14, which represents a man standing on a sidewalk at night, with an arc lamp directly over his head. The arc lamp is represented by A. The direction of the rays of light by AD, and the shadow of the man cast upon the walk as BC. When the source of light is directly *over* the man the only shadow that is thrown at all is a small spot directly at his feet. Now suppose that the man takes a step forward and assumes the relative position with the arc lamp as shown in Figure 15. His shadow begins to take shape, but it is considerably shorter than the actual height of the man. If he now takes another step forward, as shown in Figure 16, the shadow will assume its correct length; that is, equal to the height of the man. Once more, suppose the man took another step forward, till the relative positions of the man and the lamp are as shown in Figure 17. The shadow is now much longer than the height of the man. It is an elongated shadow. If he were to continue to advance, the shadow would also continue to elongate, till, at length, when the lamp was directly behind the man the length of the shadow would be 'infinity.' We see, therefore, that, as the relative positions of the object and the source of illumination vary, so the length of the resulting shadow upon the screen varies from nothing to infinity.

In the dental radiograph the shadows of the teeth upon the film would also vary from nothing to infinity, according as we changed the position of the X Ray tube. We must be able to determine just where to place the tube in order to get a resulting shadowgraph of the teeth with correct root-lengths.

Let us again refer to Figure 16—the plane of the object will be represented by the line EDB, and the screen by the line BC. These two lines form, with each other, the angle EBC, which in this case is a right angle. If we bisect this angle we get the line FHB, and we note that the direction of the rays indicated by the line AHC is perpendicular to the bisecting plane at the point H. When this takes place the resulting shadow will be the same length as the object.

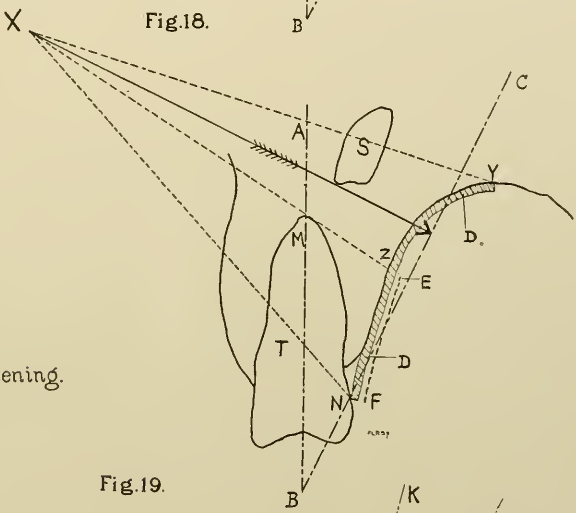
From the above illustration we may formulate a rule for the directing of the rays of light to fall upon a given object, so as to get a correct shadow length upon a screen placed at an angle to the object. This rule may be expressed as follows: 'Bisect the angle made by the plane of the object, and the plane of the screen, and direct the rays so that they will fall perpendicular to this bisecting plane.'

Let us see how this rule works out as applied to the taking of a radiograph of the teeth. Figure 18 represents a sectional diagram of a superior right bicuspid tooth situated in its socket in the alveolar process of the superior maxilla. T is the tooth, S represents the antrum or maxillary sinus, and D the film placed in the mouth and pressed up into the curvature of the palate. The line AB represents the plane of the teeth, and CB the mean or average plane of the curved film. Suppose we place the X Ray tube at X, and direct the rays, as shown by the arrow, perpendicular to the plane of the tooth. Will we get a correct shadow length of the roots of the tooth upon the film? We will plot out the projection of the tooth upon the film and see. Draw two lines from the tube X to either end of the film, as XY and XF. These lines intersect the tooth at M and N, therefore a shadow of that part of the tooth between the points M and N will be projected upon the film D, and will have the length of the dotted line EF. This line is much longer than the line MN, consequently we have, in this case, considerable elongation. The apex of the root will not be shown at all upon the film, since, if we draw a line from the tube X to the apex of the tooth's root



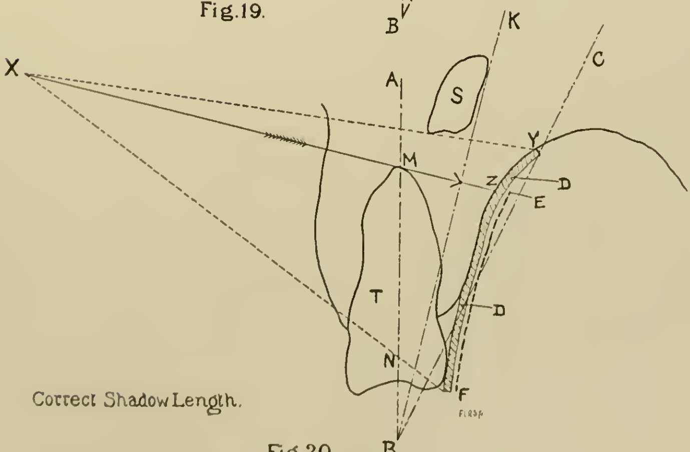
Elongation.

Fig.18.



Fore-shortening.

Fig.19.



Correct Shadow Length.

Fig.20.

(See pages 102 and 104)

and continue it to Z, we see that it does not touch the film at all.

From this diagram we learn that in the *superior arch we cannot direct the rays perpendicular to the plane of the teeth.*

Referring now to Figure 19, we will direct the rays perpendicular to the mean plane of the film. In this case the projected shadow of the tooth EF is shorter than the actual tooth length, therefore we see that *by directing the rays perpendicular to the mean plane of the teeth we get foreshortening in the root lengths.* We note, however, that in this diagram the line XY, representing the extreme upper limit of the field of the picture, passes through the antrum, and gives us a shadow of its lower half.

In Figure 20 the line KB represents a plane bisecting the angle made by the plane of the teeth, AB, and the mean plane of the film, CB. If we direct the rays perpendicular to this bisecting plane, and at a point opposite the apices of the roots of the teeth, the resulting radiograph will give us approximately correct root-lengths, as shown by comparing the lengths of the lines EF and MN. Note carefully the relative positions of the X Ray tube, and the film, to obtain this result. Of course the position of the tube, as regards the exterior part of the face of the patient, will vary according as the patient has a high or a low palate.

Suppose we had to obtain a radiograph of the maxillary sinus, we would raise the tube up still higher than as shown in Figure 19, and direct the rays downward, in a line just passing under the patient's eye. Of course the film should be placed higher across the palate, in which case only the apices of the roots of the teeth will show on the lower part of the negative.

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CHAPTER XIII.

Technique of Taking the Picture

Before taking a dental radiograph the operator should ascertain, whenever possible, the 'suspected' condition of the patient that renders the radiograph desirable. Of course this is not always evident, but there are times when we wish to inspect a certain root-canal as to the extent that it has been filled, for example, or again, we may be looking for the presence and position of an unerupted tooth. In the first case we should take the picture so that the resulting shadows would be of the correct length. In the second case the actual root-lengths are not at all necessary to show; in fact, we should purposely foreshorten the shadows on the radiograph, so as to cover the area above the roots of the teeth, where the missing tooth is most likely to be. We should always endeavor to so direct the rays as to show with the maximum clearness the area that we believe to be involved. From this you will see that we do not, in every case, try for correct shadow lengths, but in many cases—in fact, we may say the majority of cases—we deliberately distort the shadow lengths for the purpose of covering a higher area. The only distortion, however, that we consider permissible is that of foreshortening. *Under no conditions do we elongate the shadows.* Pictures showing any such distortion are evidence of faulty technique. Foreshortening the shadows does not render them any the less clear, as does elongation, but rather it tends to intensify the detail. In cases where we deliberately foreshorten the shadows we take this fact into consideration in the subsequent translation of the radiograph.

Let us suppose that we are thoroughly equipped for the taking of dental radiographs, with an up-to-date outfit, we will say, a coil installation, and a patient presents with a history of

a fistulous tract in the region of the superior right bicuspids, discharging pus into the mouth. We presume that there is an abscess somewhere, we might attempt to locate it without resorting to the X Ray, but we would only be wasting the patient's time and our own as well. We turn, therefore, to a radiograph. Let us follow, step by step, the procedure in the taking of this radiograph.

We first see that the patient is *comfortably* seated in the dental chair, or some other chair with a good head-rest. The head should be so adjusted that it is almost erect and securely placed in the head rest. We then proceed to the preparation of the film. Films and plates should be always kept in a lead-lined, X Ray proof box, or else in a room far removed from the operating room, otherwise they might be prematurely exposed, if the tube shield should be pointed in their direction. We take a film, therefore, from our lead-lined box and wrap it in palate rubber, unless it is one that has been already made waterproof. We are careful in wrapping it that we get the sensitive side of the film package against the red rubber. The film is then placed back in the box.

We next examine carefully the patient's mouth and note whether the palate is high or low. If we are not experienced in the taking of these pictures we should proceed at this stage with deliberation and special care. We consider the area we wish to show. As it is a suspected abscess condition the direction in which it points is unknown. The antrum even may be involved. We wish to show as much of the area above the teeth as we can without sacrificing the roots themselves.

We must, accordingly, foreshorten the shadows somewhat. We come to the conclusion that if we place the tube so that the rays are directed perpendicularly to the *plane of the film* we will include considerable area above the roots of the teeth, and will show even the floor of the antrum. (See Figure 19.) It is not as easy to direct the rays perpendicular to a given plane in practice as it is to plot it out on paper.

However, with a little practice, this will come by instinct. The experienced operator subconsciously places the tube in the position to best show the condition, depending on the height of the patient's palate. For this reason it is well, from the start, to note very carefully this height in each case, and to associate it in your mind with the position in which you place your tube. For the beginner, it is well to actually plot out on the patient's face imaginary lines that coincide with the planes of the teeth and the film, and even the bisecting plane.

In nearly every case certain 'landmarks' will present which will serve as guides to these imaginary lines. For example, with the case we have assumed, let us suppose that the mean plane of the film in the mouth coincides with an imaginary line drawn on the patient's face from the right-hand corner of the mouth to the inner corner of the left eye. *With this imaginary line in mind,* move your tube shield till the direction of the rays, as they will come through the opening, will fall perpendicular to a plane passing through the face along the imaginary line.

When you have the tube shield adjusted to the proper angle caution your patient *not to move the head under any consideration,* and then connect the wires to your tube shield. Be particular to see that the wire connected to the valve tube side of the coil leads to the anode of the main tube. When this is done tell your patient that you are going to turn on the current, and that there may be a slight noise of sparking, but not to 'jump' or change the position of the head. Now close the switch of your 'primary' circuit and allow the current to pass for about *two or three seconds only.* Note whether the current is passing through the tube in the right direction by observing if the hemispheres of activity and non-activity are well marked. Also note if the coloration is good, indicating the proper degree of vacuum, and that the current is not jumping to any nearby object.

If all appears well in this flash-view, flash it again "to make assurance doubly sure." Then, still finding everything

all right, wash your hands thoroughly, procure the film that you have wrapped from its box and take off the cloth covering from both sides of the palate rubber, bend the package in your fingers several times to make it flexible, and insert the package in the patient's mouth, being careful to place the *red or sensitive side toward the tube.* Press this well into the curvature of the palate, being particular not to let the inside top corner come in contact with the soft palate if you can possibly avoid it. Now remove your fingers, first telling the patient to put the left (in this case) index finger on the film and to gently press it steadily against the side of the roof of the mouth. Once more look to the position of your tube and see if in placing the film in the mouth you upset the proper angle; if not, tell your patient that you are going to take the picture and *to keep absolutely motionless.* If your type of apparatus allows the taking of the picture in but a few seconds caution your patient, in addition, to take a long breath and hold it.

Now, stop-watch in hand, or at least a watch with a second hand, close your switch sharply and make the exposure, timing it very carefully. During the exposure observe the appearance of the tube, whether the vacuum is lowering or not, the reading of your milliamperemeter, if you have one in the secondary circuit; and above all, *watch your patient,* and see if you observe any movement. If you do, stop the exposure and take another.

When the exposure is complete, open your switch and remove the film from the patient's mouth. This done, strip the *rubber* from the film packet, write its number on the back, put it in an envelope with the name and other data on it and return the paper film packet to the lead-lined box. Disconnect the tube and move the shield away from the patient's chair.

The above procedure should be followed as closely as possible in every case. Of course there will be circumstances that will alter each individual case, and they will have to be dealt with accordingly.

In radiographing the *inferior molars and bicuspids* the film will be about parallel to the plane of the teeth, and the rays can be directed perpendicular to it. In all other cases you will have to take into consideration the bisecting plane or the film plane. Try, wherever possible, to get the upper edge of the film flush with the morsal surfaces of the teeth in cases of the lower arch.

In some cases you may have trouble getting the patient to hold the film in the mouth. *NEVER, UNDER ANY CIRCUMSTANCES, HOLD THE FILM IN THE MOUTH YOURSELF DURING THE EXPOSURE!* This caution cannot be emphasized too strongly. The temptation is often great to hold the film in a difficult case, *but don't do it!* Your hand, in holding the film, receives as much exposure as the patient does, which in itself is negligible, but if you do it once you are apt to repeat it with other cases, and before you are aware of it you have exceeded the limit of safety and will develop a case of dermatitis. The effects of the X Ray are unfortunately accumulative, and an exposure of ten seconds to-day, twenty to-morrow and twenty next week, and even ten next month, would have the same effect as one minute exposure at one sitting. There are many of the early operators who have lost their fingers, hands, arms, and even their lives, as the result of exposure years ago, before the danger of the ray was known. It is not so much the direct effects (the dermatitis) that is so serious, but it is the X Ray cancers that develop on the seat of the old dermatitis years later. Be warned in time and you will find that there is no more danger in radiology as practiced to-day than in photography itself.

In cases where you may have trouble in getting the patient to hold the film in the mouth, you may be able to get someone who, perhaps, is accompanying the patient, to do so. If this is impossible there is always one method that we can use, which we will consider when we come to the technique of stereoscopic dental radiography.

The distance of the tube from the face makes a good deal of difference in the time of exposure. The intensity of the X Ray, like any other form of light, varies inversely with the square of the distance from the object illuminated. It is not well to have the tube too close, because the shadow will be enlarged. In practice 18 to 24 inches will be about right. Whatever distance you adopt, with your outfit, keep this distance constant in all your pictures. It is not advisable to have too many variable factors in your technique. The more constant we keep the conditions under which we work the better will be our results.

The four most difficult radiographs to get in the mouth are the four third molars. The superior third molars, and even the second and first, are hard to get, because the inside top corner of the film packet is apt to come in contact with the soft palate and cause the patient to gag. When the patient once starts to gag there is little hope of getting the picture without anæsthetizing the palate. In placing the film in the mouth, in a superior molar case, be very careful not to push it too far back. In fact, it is better to place it in about the bicuspid region, and very slowly and carefully work it back till, at length, we get it far enough back to show the third molar area without having touched the soft palate at all. Also be careful in putting the film in, that the inside edge does not drop down and touch the back part of the tongue. If patients show any tendency to gag, caution them to take several *long and deep breaths through the nose.* If, in spite of these precautions, they commence to gag, and they often will, there is only one thing to do, and that is to anæsthetize the palate. This is done by using a 5% solution (3% with children) of cocaine, and to spray it on the hard and soft palates *with an atomizer.* They should be told not to swallow any more of the solution than they can possibly help. In about five minutes after this operation you can proceed to the taking of the picture without any more trouble.

The inferior third molars are hard to get in many cases, because the corner of the film is apt to dig into the floor of the mouth under the tongue. The film should not be cut if you can possibly avoid doing so. In these cases we should remove the packet from the mouth, and taking the two rubber surfaces over the offending corner, between the thumb and forefinger of the right hand, and holding the rest of the packet securely with the other hand, pull out the rubber a little at the corner and then pat it back again. This should make a little pad or cushion over the sharp point of the film. Another method is to bend the corner back and so give it a rounded effect. Either of these methods is usually sufficient, but there are some cases, with a very small mouth, where it is absolutely necessary to cut off the corner. This, of course, must be done in the dark room with the aid of the red lamp. The black rubber can then be pulled down over the cut and lapped over. However, if this is done the rubber must not be removed till you are ready to develop it in the dark room. And that should be as soon as possible after taking. Also the packet should not be exposed to any bright light, but should be shielded as much as possible by the hand. The safer method, though, if you have the time, is to unwrap the film in the dark room, cut the corner of the film itself, rewrap it in its black paper, turning over the corner of the paper where you have snipped off the film, and then rewrap the packet in palate rubber.

In taking pictures of the inferior teeth always *try* to get the film down low enough to show the lower border of the inferior maxilla. This is not always possible, but if you proceed gently, but slowly and firmly, watching carefully for the wincing of the patient, you will be surprised in many cases how far down you are able to press the film.

In pictures of the inferior centrals the patient's head should be dropped very far back in the head rest, and the tube shield placed over the chest. The rays should then be directed perpendicular *to the plane of the film.*

Before leaving the subject of the technique of taking the picture, we will summarize the steps that should always be observed. It would be well for the beginner to commit this procedure to memory, rather than to hesitate in the presence of the patient. There is nothing so disquieting and less reassuring to the patient than signs of indecision on the part of the operator.

In the taking of a dental radiograph always proceed as follows:

FIRST. GET THE PATIENT COMFORTABLE.

SECOND. PREPARE THE FILM IF YOU HAVE NOT ALREADY DONE SO.

THIRD. EXAMINE CAREFULLY THE PATIENT'S MOUTH.

FOURTH. ADJUST THE TUBE SHIELD TO DIRECT THE RAY PROPERLY.

FIFTH. CAUTION THE PATIENT NOT TO MOVE THE HEAD.

SIXTH. CONNECT UP YOUR TUBE AND FLASH IT TWICE.

SEVENTH. WASH YOUR HANDS THOROUGHLY.

EIGHTH. INSERT THE FILM PACKET IN THE MOUTH.

NINTH. REMOVE YOUR FINGERS, AND LET THE PATIENT HOLD THE FILM.

TENTH. READJUST YOUR TUBE-SHIELD IF NECESSARY.

ELEVENTH. AGAIN CAUTION YOUR PATIENT TO KEEP ABSOLUTELY STILL.

TWELFTH. TURN ON THE CURRENT AND MAKE THE EXPOSURE.

THIRTEENTH. REMOVE THE FILM FROM THE MOUTH, AND WASH YOUR HANDS AND THE RUBBER PACKET.

FOURTEENTH. DISCONNECT THE WIRES AND MOVE AWAY THE SHIELD.

FIFTEENTH. STRIP OFF THE RUBBER COVERING FROM THE FILM PACKET.

SIXTEENTH. WRITE NUMBER AND NAME ON FILM PACKET.

SEVENTEENTH. PUT FILM PACKET IN ENVELOPE.

EIGHTEENTH. PUT ENVELOPE IN LEAD BOX TILL READY TO DEVELOP.

Learn these eighteen steps carefully and always observe them as far as possible. The author has found, by the experience of many years, that these steps are all necessary and should be adhered to in their right order if satisfactory work is to be accomplished.

Particularly in clinic work should these directions be insisted on.

NOTES

FILM CLAMP

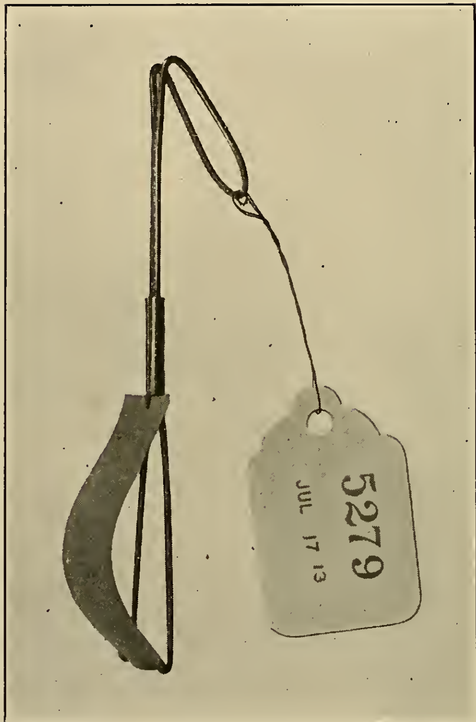


Figure 21—(see page 119)

CHAPTER XIV.

Development and Mounting of Negatives

The development of X Ray films is carried out very much the same as with ordinary photographs. The operator who has had any experience with amateur developing should find this the easiest part of the subject.

The first requisite is a dark room. This can be a closet that has been fitted with a table or wide shelf, about three or four feet from the floor, and preferably electric light for the dark-room lamp. Red lamps may be purchased from any photographic supply store to burn either electricity, oil or candles. Running water is also desirable in the dark room, but it is not essential, providing you can use it in another room. Dental films should not be developed in photographic trays, but tumblers or small glass troughs should be used. Three of these should be provided. The author has found that the rectangular trough-covers of butter dishes, that may be bought in the nearest 10-cent store, answer admirably, the bottoms of which can be used for covers. The films are hung in these dishes, or where only two or three negatives are to be developed at a time, ordinary tumblers will answer perfectly. Throughout the entire operation of developing, fixing, washing and drying, the films are held in small clamps that were devised by the author many years ago. They may be obtained from the American X Ray Equipment Co., of New York. The accompanying illustration shows how the film is held in the clamp (Figure 21). Small tags are attached to each clamp, on which is written the serial number of the radiograph, or even the patient's name. In this way the negatives are never mixed up while developing several at one time. The operator should have at least a dozen

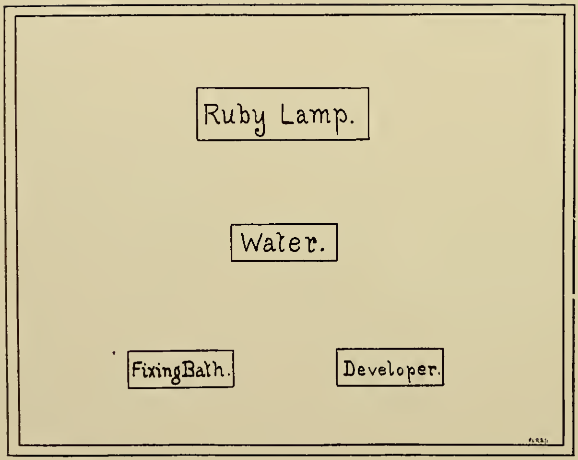


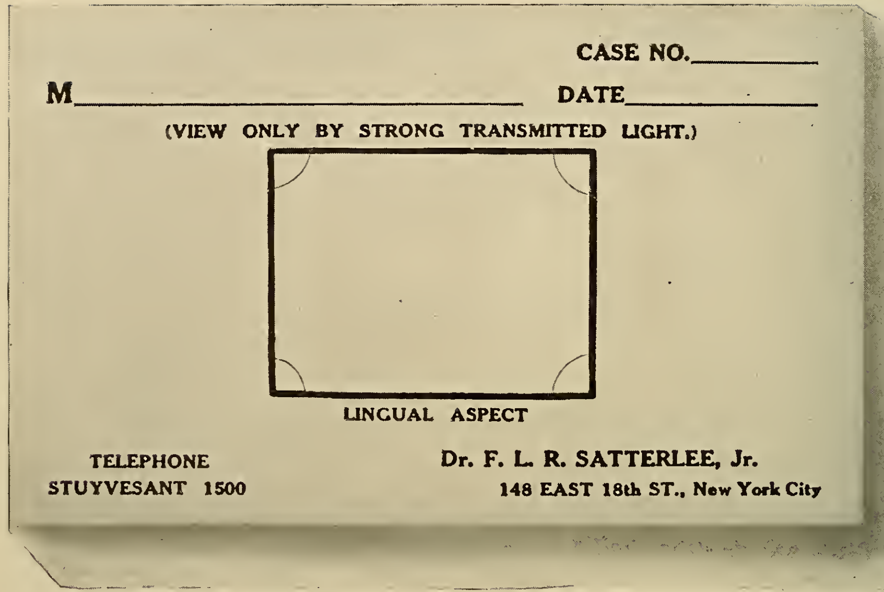
Figure 22—(see page 121)

of these clamps on hand, and if he expects to do much work several dozen will be found very desirable.

The developer used in dental work is far more concentrated than the ordinary photographic developers. The formula that is best to use will be found in the package in which the dental films are bought. Different manufacturers of dental film advocate different formulæ for development. The formula for the fixing bath is also given in the direction sheets that accompany all makes of films.

The technique for developing is as follows: We will suppose that we have taken two radiographs and are ready to develop them. We go into the dark room and before shutting out the white light prepare the solutions and film clamps. We take three glass troughs that have been well washed, and fill one of them with water and place it as shown in Figure 22. Fill another with the developing solution and place it on the right, while the third is filled with the fixing bath and placed on the left, as shown in the diagram. A towel is also provided and placed alongside the troughs on the shelf or table.

Four clamps are now tagged and the number of the first film is written on two of them, while the number of the second film is written on the other two. Each pair of clamps, with its corresponding film packet, are placed on the shelf some distance apart, so that no mistake can be made in the dark, and the wrong films placed in the clamps. When everything is ready, light the red lamp and put out any other white light and close the door of the dark room. Take one of the film packets and open it. Take only one of the films out, holding the other wrapped in the black paper in your hand and place the film in the clamp. Be sure to get the sensitive or dull side out, or away from the clamp. The dull side can be readily distinguished from the shiny side, by holding the film in front of the red lamp and catching the reflection of the light on its surface. The dullest reflection is the sensitive side.



CASE NO.__________

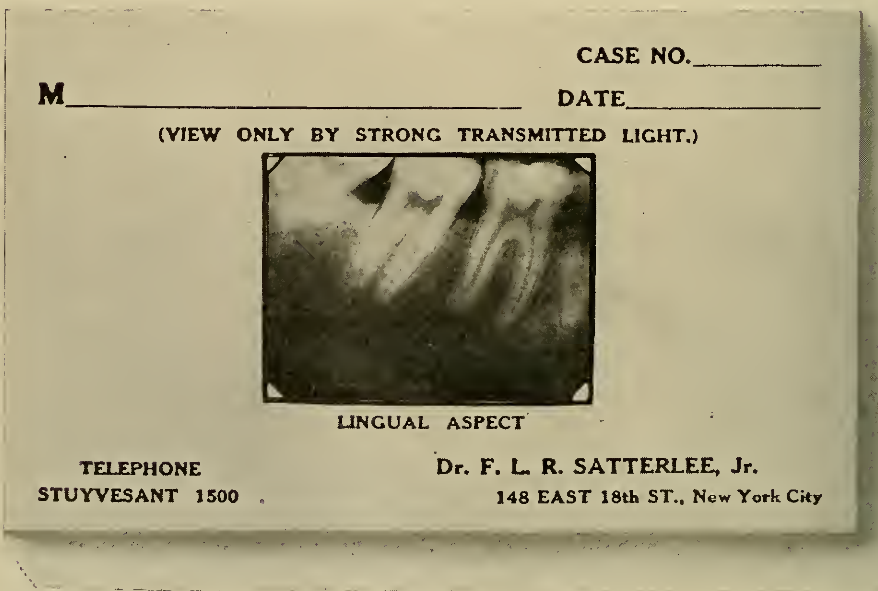
M______________________________ DATE____________

(VIEW ONLY BY STRONG TRANSMITTED LIGHT.)

LINGUAL ASPECT

TELEPHONE
STUYVESANT 1500

Dr. F. L. R. SATTERLEE, Jr.
148 EAST 18th ST., New York City



CASE NO.__________

M______________________________ DATE____________

(VIEW ONLY BY STRONG TRANSMITTED LIGHT.)

LINGUAL ASPECT

TELEPHONE
STUYVESANT 1500

Dr. F. L. R. SATTERLEE, Jr.
148 EAST 18th ST., New York City

Figure 23—(see page 123)

When the first film is in the clamp, hang it in the glass trough containing water. Now take the other film from the packet you are holding in your hand and place that in the other clamp. Hang this also in the water. Take the first film and clamp and move it up and down a few times, to be sure that the surface is thoroughly wet and that no air bubbles adhere to it. Place it in the developing solution on the right. Do the same with the second film.

Observe that the film is whitish and translucent by transmitted light, when first placed in the developer. Take the films out from time to time and hold them up to the red lamp for a few seconds at a time only. Watch the image appear on these first pictures by occasional inspection. The films are kept in the developing bath until, on looking through the film at the red light, the whole film looks quite black, and no *detail* is discernible. Then remove the films from the developer, and rinsing them by dipping them a few times in the water, transfer them to the fixing bath. You can now proceed with the other two films in the second packet. Until you are thoroughly familiar with the developing operation, it is not well to open a second packet till you have the first films in the fixing bath. The films are left in the fixing bath until they have cleared as much as they will, about ten minutes. They are then taken out and hung back in the water bath. After all the films are 'fixed,' that is, made non-sensitive to actinic rays, the white light may be admitted to the room.

The films are now hung in another large vessel, such as a battery jar, or a deep tray, and this is placed under a tap of *running cold water* for about twenty minutes or longer. They may then be hung in an empty battery jar to dry, first swabbing them off *very lightly* with a small piece of wet absorbent cotton. Care must be taken not to dislodge the film from its clamp in this operation. Do not fail to immerse the films in water, *before and after,* both the developing and fixing baths.

When the films are thoroughly dry they are then ready for mounting. Figure 23 represents a mount devised by

the author for dental negatives. These mounts consist of rectangles of celluloid, 4½ x 2¾ inches. The celluloid being clear on one side and dull on the other, resembling ground glass. In the center a rectangular border is printed the size of the dental picture and slits are punched in the corners of this to take the corresponding corners of the film. The film is slipped into these mounts film side down.

On these mounts are printed the necessary blanks to be filled in for the recording of the patient's name, the case number and date. At the bottom of the mount appears your own name and address. Just below the printed rectangle appear the words, "Lingual Aspect," and directly above the directions, "View only by strong transmitted light."

These cards can be filed in an index and serve as an admirable method for the preserving of the pictures properly filled in with the necessary data. When a negative is examined by holding it up to a strong light the dull surface of the celluloid gives a fine backing and prevents the seeing of objects through it, such as the filament in an electric lamp used to view it with. Such objects tend to obliterate the detail in the picture and confuse the operator*

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* These mounts may be purchased from the Swenarton Stationery Co., of New York, printed to order with your name, etc.

NOTES

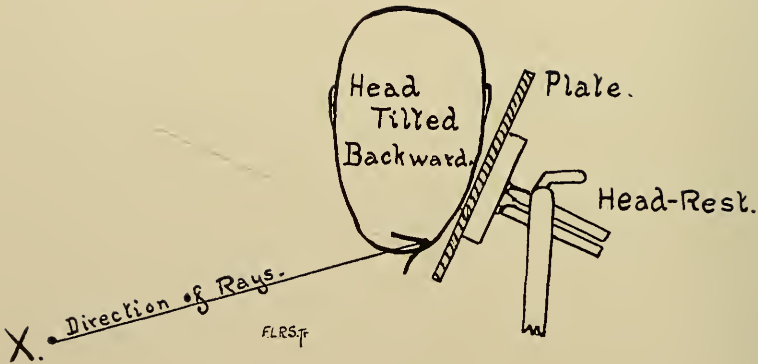

Figure 24—(see page 127)

CHAPTER XV.

Head Pictures on Plates

There are cases that arise in dental radiography where we cannot get the picture on a film in the mouth. For example, we may have a patient present with a fracture of the inferior maxilla. The jaws may be completely or even partially ankylosed, and consequently it will be impossible to get a film in the mouth. Again we may have to obtain a radiograph of the ramus or even the condyle. In these cases we must take the radiograph on a glass plate.

There are two very good X Ray plates on the market, the 'Wrattan and Wainwright,' made by the Eastman Co. of Rochester, New York, and the 'Ilford' plate, made by the Ilford Co. of London.

These plates can be obtained in both 6½ x 8½, and 8 x 10 sizes, the only sizes that we would use. They are wrapped in two thicknesses of envelopes, the first black and the second or outside one orange colored. This renders them lightproof.

The patient is seated sideways in the chair, with the head thrown away back and the involved inferior maxilla pressed against the head rest The plate is then slipped between the head and the head rest, the pressure of the head against it being sufficient to keep it in place. The tube shield is so placed as to direct the rays from the opposite side, pointing slightly upward, so that the shadow of the maxilla on the opposite side just escapes being superimposed on the affected side. It will require some little practice to get the right angle every time. The accompanying diagram, Figure 24, shows approximately the relative positions of the head, the plate and the head rest, and the direction of the rays.

These plates are developed in trays the same as any other photographic plates, only using the developing and fixing baths the manufacturers recommend in the printed slip that accompanies every box of plates.

Radiographs should not be made on plates if we can possibly show the required area on a film in the mouth. The tissues are further from the 'screen,' resulting, therefore, in a sacrifice of clearness and detail. Also, we are prone to get superimposition of the tissues of the opposite side. Many hospitals and radiologists not familiar with the special dental technique attempt to take all dental conditions on plates. This practice results in the prejudice that many dentists have against the resort to radiography in doubtful cases. They have, unfortunately, only had experience with plates that have been made for them by general radiologists without the knowledge of the special dental technique, and the finer detail that would have been of great assistance was entirely lost. Radiographs on plates of conditions of the superior maxilla are particularly unsatisfactory.

Prints of both plate and film negatives are rarely made to-day, the dentist preferring to make his diagnosis from the negative directly. Printing is a purely mechanical process and consequently there must be some loss in the transfer. The original negative has more detail than can be obtained in any print. All reproductions of radiographs in this book are negative reproductions, just as though the actual negative were before you (but there is considerable loss of detail due to the reproduction). This is done so that the student may become accustomed to the X Ray *negative* appearance of radiographs. In the negative dense objects appear white, while the converse is true with prints. Plate negatives may be marked with the operator's name and its serial number at the time of exposure. Small plates of aluminum are stamped with the name, and the letters filled in with red lead. Numbers are placed on the markers in the same manner. These name plates, or markers, are placed on the X Ray plate and are left there during the

exposure, so that, on development, a radiograph is also made of the marker which leaves only the shadow of the letters and numbers.

NOTES

CHAPTER XVI.

Dangers of the X Ray

Shortly after the discovery of the X Ray, it became known that many who were exposed to the rays developed a condition of the superficial tissues resembling in appearance that of sunburn. For some time these effects were not traced to the ray itself, but were thought to have been produced by the high potential discharge. This theory was, however, soon proved to be wrong, and it was found that the rays themselves were to blame. Experimenters then became more careful about exposing themselves to this powerful agent, that could produce these "burns" as they began to be called. Next came the reports of more effects of these wonderful rays, such as the falling out of the hair, pigmentation of the skin, and the cracking or splitting of the finger nails. In fact, in several cases severe 'burns' were reported and the complete loss of the finger nails. These 'burns' were very hard to heal, resisting all means of treatment. For awhile these alarming reports threatened to entirely discourage the investigators. It was then found that these rays, that had the power to produce such changes in the healthy tissues, could also be used to advantage in the treatment of certain pathological conditions of the skin. Interest was again aroused, and means were devised by which operators could work around these rays with comparative safety.

Since that time, now many years ago, the entire subject has been studied, analyzed and developed, until to-day we are no longer working in the dark with an unknown agent, more dangerous in its effects than even opium and morphine.

The effects of the X Ray may to-day be classed under two main divisions, *primary and secondary*. The primary effects are due to direct exposure to the rays themselves for a period

of time sufficient to produce certain changes in the skin known as *Röntgen Dermatitis*. This dermatitis may be of five degrees. The first degree resembles a slight sunburn in appearance. There is a slight pinkish erythema, dry in character, and without destruction of tissue. There may be some sensation of burning or tingling such as accompanies sunburn. In second degree dermatitis there is, in addition, the presence of vesicles and the surface becomes moist or weeping. The sensations at this stage resemble those of a blistering burn of any character. If all exposure to the rays is stopped at this point, the result will probably be a slow cleaning up of the condition and a slight desquamation, and perhaps a permanent pigmentation. Third degree dermatitis is characterized by an angry red appearance with intense congestion, which is moist and weeping all the time. Upon the raw and sometimes bleeding surface there forms a yellowish-white necrotic membrane. This membrane, however, is made up of only epithelium. The connective tissue beneath is not affected, except for more or less swelling. If all X Ray exposures were now stopped the condition would gradually but slowly subside, and in the course of two or three months the ruptured vesicles and suppurating necrotic membrane would dry up, and would, in turn, be followed by a horny epidermis that would appear in spots over the affected area. Many cases are considerably retarded by the reappearance of the vesicles, and the repetition of this process of throwing off and building up sometimes keeps up for months and even years. In time, however, the relapses cease, and the permanent horny epidermis spreads over the entire area. This new skin is quite smooth and natural looking, except for the absence of all hairs and follicles. For some time the new coating of the epidermis is quite sensitive to external irritations.

Dermatitis of the fourth degree is characterized by a still greater erythema and the degree of congestion is much more intense; in fact, the outer coating of the skin becomes mummified, in places surrounding actual ulcerations of the lower connective tissue. There are great masses of dead tissue

which, if not removed surgically, will result in gangrene. Patients suffering from this degree of dermatitis usually complain of great pain. In time, if all exposure to the X Ray ceases, even this advanced condition of necrotic destruction will clear up, but it may take years for the reconstruction to take place. In the end the new skin is hard and horny and covered in places by scar tissue.

The fifth degree of Röntgen Dermatitis may be called "chronic" dermatitis. It takes place principally on the hands of operators, and other workers around the ray, who may be exposed, from time to time, over a long period. They are continually adding to the effects without getting entirely well of the old. The skin becomes thin and atrophic with red patches of a vascular nature. There is an entire absence of all follicles and hair. Codman, in the *Philadelphia Medical Journal* (1902), describes this condition as follows: "In the less pronounced forms the skin appears chapped and roughened and the normal markings are destroyed; at the knuckles the folds of the skin are swollen and stiff, while between there is a peculiar dotting resembling small capillary hemorrhages. The nutrition of the nails is affected so that the longitudinal striations become marked and the substance becomes brittle. If the process is more severe there is a formation of blebs, exfoliation of epidermis and loss of the nails. In the worst form the skin is entirely destroyed in places, the nails do not reappear and the tendons and joints are damaged."

Other primary effects are the loss of the hair, finger nails, and even an acute toxemia with accompanying fever. This latter condition is quite rare and only develops where there is a marked idiosyncrasy to X Ray reaction. In cases where the hair of the head receives the exposure from a low or even a medium vacuum tube the hair comes out quite easily from an exposure not even long enough to produce a slight erythema of the scalp. Hair lost in this manner, however, comes back in about six weeks with a fine thick growth, providing the exposure was not long enough to destroy the follicles.

The secondary effects of the X Ray are far more subtle in their action than the primary, taking place as they do sometimes after a lapse of many years from the time of original exposure. First we will mention the development of deposits particularly around the knuckles of the hands of X Ray workers. These horny excrescences finally develop into hyperkeratosis. These keratoses sometimes have an inflamed base which, in time, gives way to an epitheliomatous degeneration. Epitheliomas developed in this way show no improvement as the years go by, and the operator is indeed fortunate if they do not spread. There are many cases of carcinoma that have for their origin the keratosis on the hands of X Ray workers. If these conditions continue to spread, the only way to check the depradation is amputation. These cases, however, only occur where the victim has repeatedly exposed himself to the X Ray and has taken no precautions. Fortunately these cases will occur no more, owing to the perfect methods of protection practised to-day. The operator who starts to-day to take up radiology can proceed without danger, thanks to the knowledge we have gained from the unfortunate pioneers who sacrificed themselves unknowingly to the cause of science.

Another secondary effect of the X Rays is its action on all embryonic tissue. This action tends to break down and destroy the developing cells. Many years after the X Ray was discovered it became known that those who had been subjected to continual exposures of short duration, in the course of their work with the rays, had become sterile, or unable to reproduce their kind. This was found to be caused by the destruction of the spermatozoa in the male and the primordial ovules in the female. The cells involved in these cases were of embryonic origin. Sterility produced in this manner is not accompanied by impotence. Whether these cases are permanently affected we are not prepared to say. Some writers believe that the condition is but temporary, and its effects will pass away as the operator ceases to further expose himself to the rays. It is more likely, though, that if the amount of

exposure has been sufficient or prolonged over a great many years that the condition becomes permanent.

There are numerous other systemic effects that are produced, and they differ somewhat in individuals. In some there is a tendency to low body-temperature; as low as 96.3 degrees F. has been observed as a normal temperature of a pioneer investigator.[1]

The student reading of these effects of the X Ray should not become frightened and hesitate to use this wonderful diagnostic agent. He should, however, fear the ray and respect it to the extent of carefully following a technique of protection that insures him against its casualties. With the modern method of procedure the protection is complete, and the operator should never be subjected to any exposure at all. Because we know that sulphuric acid is a deadly and caustic liquid we are not afraid to keep it properly bottled for use. As long as we know the danger of the X Ray, we reduce the possibilities of the deleterious effects.

The danger to the patient exposed to the X Ray is practically nil. Radiographs of all parts of the body are to-day made with the improved apparatus in but a few seconds at the most. This short exposure is not sufficient to produce the slightest effect, either primary or secondary.

Instruments have been devised to measure the dosage of the X Ray. Perhaps the most used is the Radiometer of Holznecht. By means of this device the rays emanated from a vacuum tube for the purpose of therapeutic application, or even for the taking of a radiograph, can be measured by its chemical effect upon a prepared pastil exposed simultaneously. This chemical pastil changes color during its exposure to the rays and the shade of color is compared with a scale devised by Sabouraud.

The intensity of the rays is measured in units called Holznecht's units, or as they are generally spoken of as H's. For example, the dose necessary to produce the slightest erythema on the face of an adult is equivalent to three of the

Holznecht units, or 3H. Now the greatest dose necessary for the taking of a radiograph is but a small fraction of a single H unit. From this you will see the enormous margin of safety under which we are working in the exposure of our patients. If to-day an erythema is produced on a patient, from the effect of the exposure employed for the taking of a radiograph, it is due entirely to the faulty technique of the operator. There is no excuse for such a thing happening, even where there is a marked idiosyncrasy toward X Ray effects on the part of the patient.

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RADIOGRAPHS

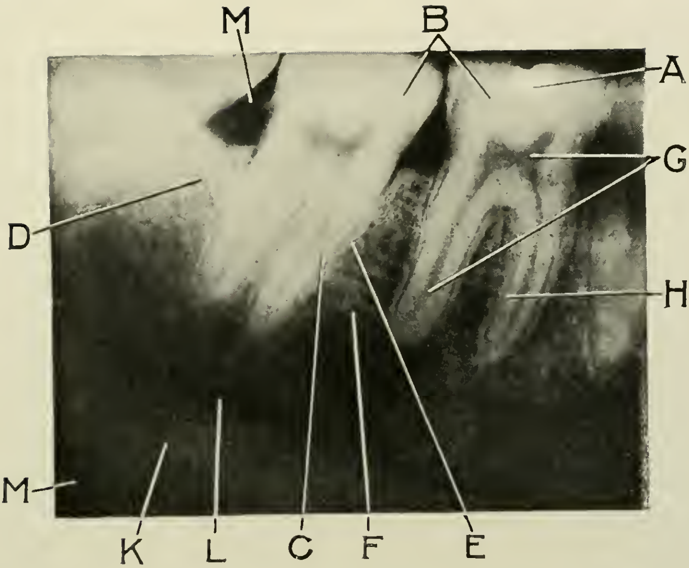

Figure 26—(see page 177)

Figure 27—(see page 178)

Figure 28—(see page 178)

Figure 29—(see page 181)

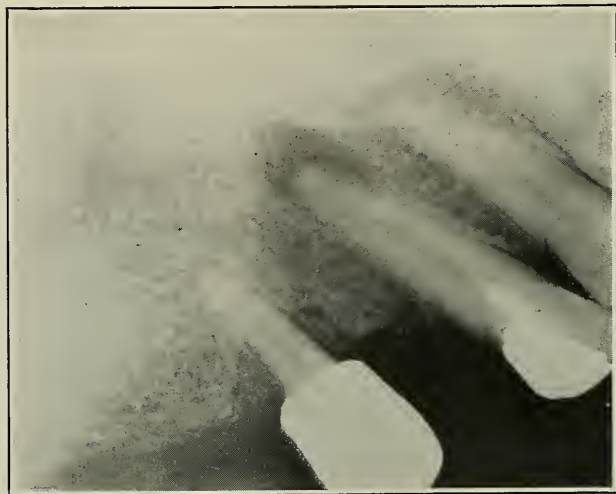

Figure 30—(see page 183)

Figure 31—(see page 184)

Figure 32—(see page 184)

Figure 33—(see page 184)

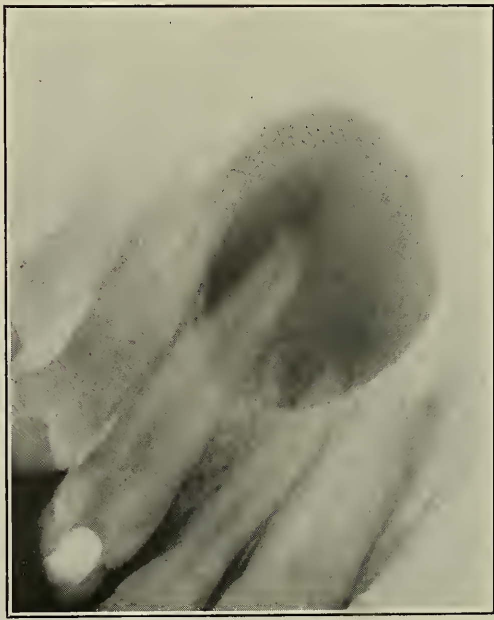

Figure 34—(see page 185)

Figure 35—(see page 185)

Figure 36—(see page 185)

Figure 37—(see page 185)

Figure 38—(see page 185)

Figure 39—(see page 185)

Figure 40—(see page 185)

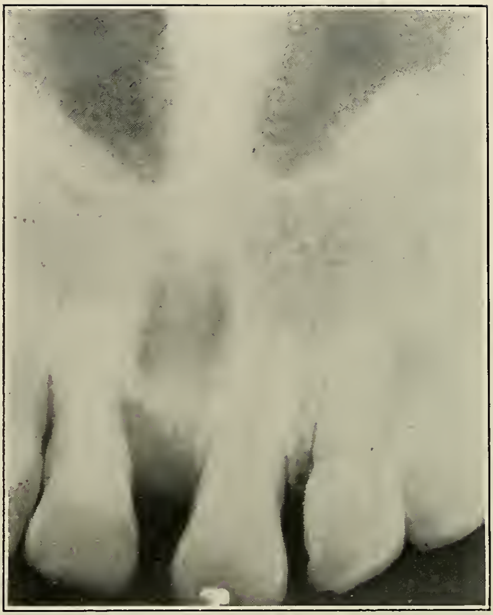

Figure 41—(see page 185)

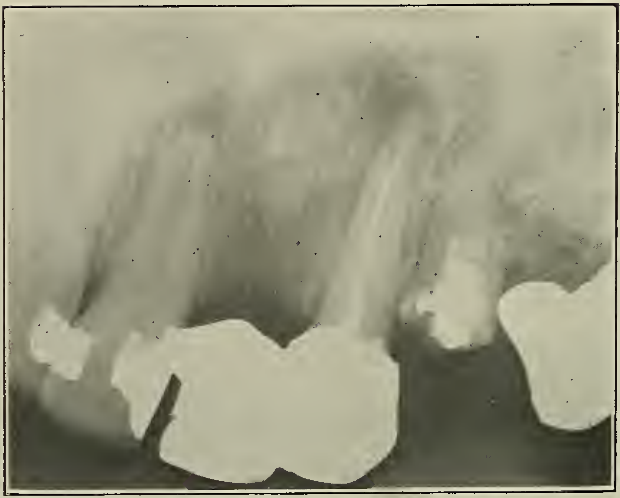

Figure 42—(see page 185)

Figure 43—(see page 185)

Figure 44—(see page 186)

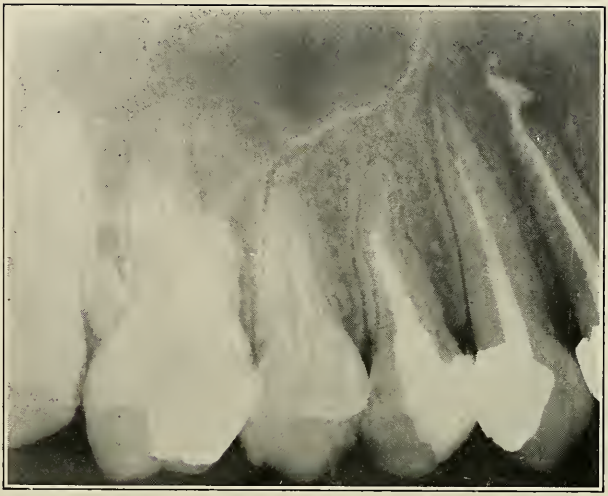

Figure 45—(see page 186)

Figure 46—(see page 186)

Figure 47—(see page 186)

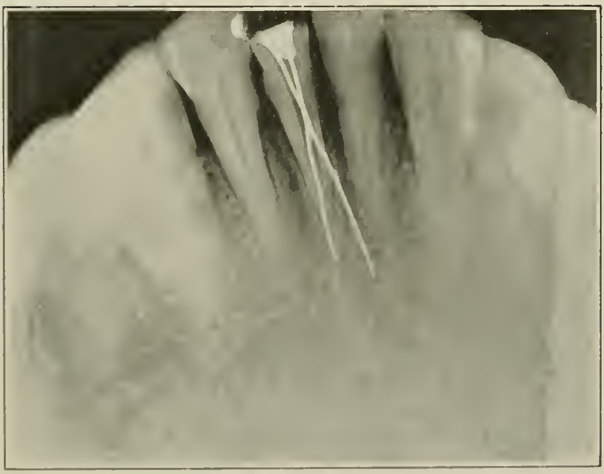

Figure 48—(see page 187)

Figure 49—(see page 187)

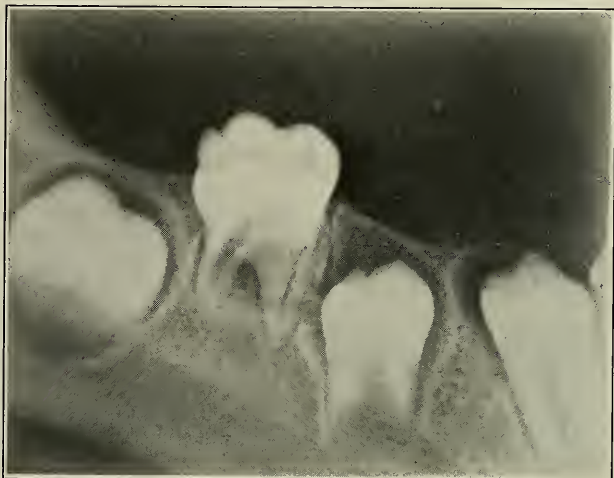

Figure 50—(see page 187)

Figure 51—(see page 187)

Figure 52—(see page 187)

Figure 53—(see page 187)

Figure 54—(see page 187)

Figure 55—(see page 187)

Figure 56—(see page 187)

Figure 57—(see page 187)

DENTAL RADIOSCOPE

Figure 59—(see page 193)

DENTAL RADIOSCOPE (Sectional View)

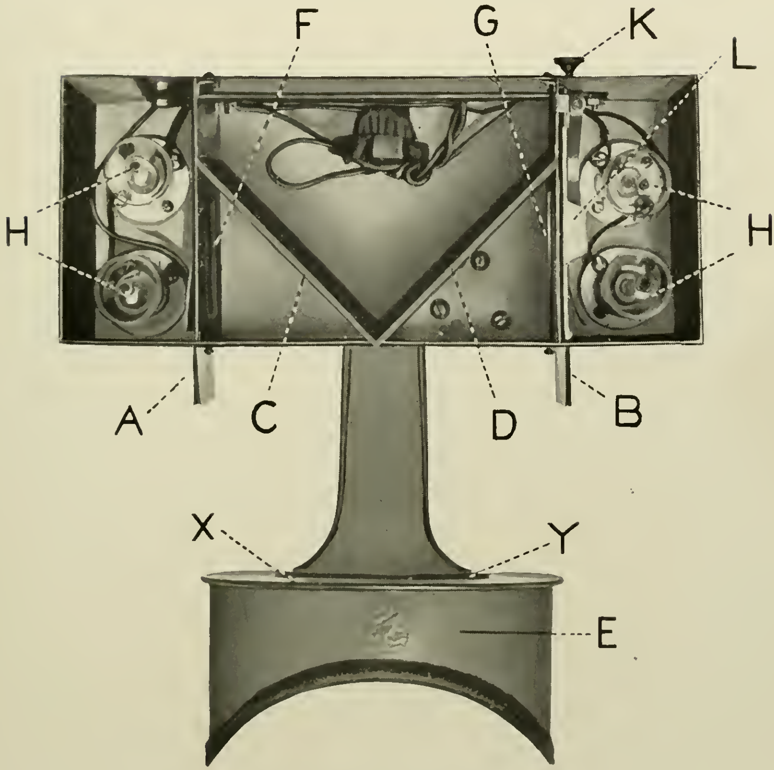

Figure 60—(see page 193)

CHAPTER XVII.

Reading the Negatives

In order to properly translate the findings of a dental radiograph we must first become familiar with the normal appearances of the several tissues involved in the dental anatomy, as shown in the X Ray negative.

The dental radiograph we have defined as 'a shadowgraphic representation of the tissues, taken in a series of planes from facial to lingual surface.' We therefore have to read the condition presented in the negative by the shadows they throw, and in most cases to read through the superimposed tissues. All tissues are represented by a certain intensity of shadow, governed by the corresponding density of the actual part. In the negative dense tissue is characterized by white areas, while tissues less dense are shown by darker appearances. Absence of tissue is indicated by black portions of the negative.

Figure 26 represents a dental radiograph enlarged to twice the actual size, and shows the normal X Ray appearances of the tissues. We will start with the lightest area shown, as 'A,' which represents an amalgam filling in the crown of the first molar tooth. The next lighter shade is seen in the crowns of the teeth themselves, as 'B.' Then we find the shadow getting darker as the density of the tooth structure becomes less, as 'C' representing the roots of the teeth. Next comes the thicker portions of the process 'D,' and then the white line 'E,' which borders the sockets of the roots. This tissue represents the most recently developed portion of the alveolar wall, and is made up of heavier deposits of lime salts. 'F' marks the grade of density shown by the white lines that represent the divisions between the interstices of the alveolar process. All cancellous bone tissue is characterized in its X Ray appearance by this whitish network structure. The next gradation of density is shown by the appearance of the pulp chambers

and canals of the several teeth 'G.' The pulp itself being essentially soft tissue is not shown in the radiograph, but the space occupied by soft tissue is outlined by dark areas. This is also illustrated by the space occupied by the periosteum, or peridental membrane, lining the tooth sockets shown by the line 'H' surrounding the roots. The compact bone tissue 'K' is in this case shown as having little density. This dark appearance in the radiograph is caused by the very thin structure of the inferior maxilla at this point. This degree of density varies greatly in individuals, and no approximate gradation of shade can be established to characterize the normal appearance in all cases. We can also see a still darker line running through the compact bone tissue and parallel to the lower border of the maxilla. This dark line, 'L,' is the inferior dental canal. The blackest part of the picture is the area, 'M,' which represents the complete absence of tissue, as shown by the spaces between and above the crowns of the teeth.

This radiograph, as shown in Figure 26, should be carefully studied and compared with Figure 27, which represents a still greater enlargement from the same negative. These various gradations of density should be borne in mind constantly as representing the normal X Ray appearances of the dental tissues. Now turn to Figure 28 and observe how these comparative densities will appear in the actual size radiograph without enlargement. In practice you will have to make your diagnosis from this small normal-sized picture; therefore it would be well to compare it carefully with the two enlargements from the same negative. All other radiographs illustrating the various pathological conditions we will reproduce as negatives enlarged to twice the size, for the purpose of amplifying the finer detail that might be lost in the process of book reproduction.* In stating that these enlargements are twice

* It is absolutely impossible, with printer's ink, to faithfully reproduce all the fineness of detail and contrast that we can see on the translucent negative viewed by transmitted light. The twofold enlargement of the negatives serves to bring out, to a certain extent, the finer lines of detail, but owing to the additional process, there is a corresponding loss of contrast or gradation between light and dark areas. As these radiographic negatives are reproduced primarily for the instruction

the size of the original negative it must be understood that each dimension of the picture is twice as large, although the actual area of the radiograph is four times as great.

The next important step, after differentiating between the shadows that indicate the densities of the several parts of the dental negative, is to correctly get our bearings in regard to the teeth we are looking at, and their positions relative to the part of the mouth in which they are situated. This is called 'orienting' the picture. The reproductions in this book are the same as though we looked through the glossy or non-sensitive side of the film, and represents the *lingual* aspect of the teeth and surrounding tissues in all cases. From this we will note that in the first radiograph we show, from left to right, the third, second and first molars, and part of the second bicuspid of the inferior left maxilla. Another fact that we must consider in the translation of the radiographs, is that in some cases only two or three teeth in the center of the picture show very clearly, while the others, particularly those at the edges of the film, are more or less indistinct. This is caused by the curvature of the arch which brings two or three teeth directly in the field of the rays, while the others are more or less superimposed on each other, or else are distorted by the curvature of the film conforming to that of the palate, and so destroying the uniformity of the angle that the direct rays from the tube, form with the film.

We have seen how the various gradations of density of the several parts may be compared on the individual radiograph, but these gradations in one picture cannot be compared with the relative densities of another, which may have been taken under different conditions of penetration in the X Ray tube. A slight difference in degree of vacuum in the tube will give marked variations in the relative contrasts of two pictures.

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of the student, the author has permitted, *in a few cases,* a certain amount of retouching of these enlargements, under his personal supervision, to the extent only of strengthening the contrasts between light and dark areas, so that they may approach the actual gradations seen in the original negative. *In no case has detail been inserted or gradations brought out that could not be seen in the original film.*

NOTES

CHAPTER XVIII.

Diagnosis of Pathological Conditions

Having considered the normal appearance of the dental tissues under the X Ray, we will now turn our attention to the variations from the normal that we meet with in the presence of pathological conditions. Let us first consider a typical case of alveolar abscess. Where an abscess takes place in the alveolar process, we always have an accompanying destruction of cancellous bone tissue. From our consideration of the normal picture we have learned that absence of tissue is characterized on the radiograph by dark areas. We, therefore, must look for a dark area in the case of an alveolar abscess. Let us examine Figure 29 (Case I.). Here we see, from left to right, the superior left first bicuspid, cuspid and lateral incisor teeth. We note that the bicuspid is capped, the gold crown showing very white, owing to its density, and we also observe that this cap does not accurately fit the crown of the tooth. Above the gold cap is seen a white line running upward in the root canal and extending about two-thirds of the way to the apex. From its whiteness we judge that it must be some very dense substance, and we come to the conclusion that it must be filling material. Note particularly that the apical end of the canal is not filled, and then observe the circumscribed dark area in the alveolar process surrounding the apex of the root. This dark area indicates lack of density or absence of tissue. In this case the density of the process should be homogeneous, therefore we are led to believe that an actual cavity (to account for the absence of tissue) must exist. It is too small and too low down to be the maxillary sinus, therefore we are led to believe that its existence must be due to some pathological condition. Where these dark areas are found in the alveolar

process, and are not natural cavities, such as the antrum and the nasal cavities, and where they are markedly circumscribed, that is having a distinct and abrupt line of demarkation between the dark area and its surrounding tissue, we can, in nearly every case, make the positive diagnosis of alveolar abscess.

If the abscess cavity contains any quantity of pus the area is generally particularly dark. This is caused by the fact that *pus has been found to be fluorescent* under the influence of the X Ray. This fluorescence increases the radiations that affect the film in this particular area, consequently producing a greater reaction on the sensitive emulsion, which shows on the negative as accentuated dark areas. From this we deduce the fact that in many cases where the area is particularly black the abscess cavity will probably contain pus.

In the case in question (Figure 29) we note that the area is circumscribed and that it is decidedly dark as compared with the normal tissue. We can safely say that in this case we have a well-developed alveolar abscess that is quite active.

The etiology of this abscess is also quite apparent and, furthermore, was borne out by the clinical history. The patient, a Mr. D., presented at the Clinic, with intense pain, over the region of the bicuspid that had recently been capped. The radiograph was taken and the diagnosis of alveolar abscess was at once made certain. The cap was removed, the filling material drilled out, and drainage established through the apex. The pain disappeared and the condition commenced to improve. After the canal had been open for some days and the active process subsided, the canal was again filled, but this time to the apex, and the cap once more replaced.

In this case the pulp had been devitalized, and in the removal some of it was left at the apical end of the canal. This portion of the dead pulp was sealed in by the filling material that partly filled the canal, with the result that the gases of putrefaction were given off and forced through the apical foramen, starting up an inflammation of the pericementum. If a radiograph had been taken at this stage just a

slightly enlarged portion of the dark line surrounding the root would be apparent at the apex. Pericementitis may be determined by the X Ray, even before the patient feels any real pain. In the case in question the pericementitis was not taken care of, and the condition went on to the stage of abscess with its consequent destruction of tissue, and the formation of pus, before the patient presented for treatment. If radiographs were taken from time to time after an abscess area has been evacuated and drained, the process of repair will be seen. At first a distinct whitish line will be noted surrounding the area of destruction. This line indicating increased density, probably represents an extra deposition of lime salts over the walls of the abscess cavity, being an effort of nature to check the further destruction of cancellous bone tissue. Granulation would then be noticed by the slightly whitish tint inside the white line of demarkation. This would gradually fill in toward the center of the cavity, and the shade would get lighter and lighter as the density of the tissue increases. As osseous tissue in time develops, the density of the abscess area more closely resembles the healthy tissue adjacent to it, and, in fact, ultimately takes on the characteristic network appearance of the normal alveolar process.

Before leaving Figure 29 we will call attention to the absorption of the alveolar process consequent to the extraction of the second bicuspid and molar teeth.

Case II., Figure 30, represents another typical case of alveolar abscess surrounding the apex of the superior left lateral incisor tooth. In this case the pus sac has ruptured and the pus has infiltrated into the surrounding process as indicated by the slightly darker appearance extending downward toward the roots of the bicuspid and central incisor teeth. This darker appearance is caused in all probability by the fluorescence of the pus, and not to any destruction of tissue. If the condition were allowed to go on, however, necrosis would inevitably set in. The cause of this abscess is the same as in Case I., and the partial root filling is to be particularly noted.

Case III., Figure 31, shows another abscess on the distal root of the inferior right second molar. Again, note the piece of filling material just at the opening of the distal root canal. The operator in this case was under the impression that the root had been perfectly filled!

Case IV., Figure 32, represents another alveolar abscess involving the superior left central and lateral incisor teeth. In this case the repair is taking place and the root canals are refilled. Note the appearance of the filling-in tissue, the only very dark area remaining, being directly around the root of the central. Above the abscess area there appears a white line running obliquely downward toward the median line, with a dark area to the right of it, and one to the left of it higher up. The former area represents the nasal cavity and the latter the anterior part of the left maxillary sinus. The white line is the floor of the nasal cavity. Note the increased density of the maxillary suture. At the apex of the right central we see a slightly dark area, indicating the presence of an inflammation of the periosteum. This is hardly large enough to be classed as an abscess.

Case V., Figure 33, shows an active abscess in the socket of the superior left lateral incisor tooth, which has been extracted. A slight involvement of the apex of the cuspid is also seen. Above the bicuspid region you will note two dark areas surrounded by a white line. These areas represent two chambers of the antrum cavity, the white lines indicating the exterior walls, the shadows of which are thrown downward and superimposed over the alveolar process. The dark area inside denotes the normal antrum cavity. The heavier white line above represents the osseous tissue dividing the posterior floor of the nasal cavity and the hard palate. Note that the antrum cavity is seen to extend above this white line, due to the superimposition of the shadows. This representation of the antrum cavity is seen quite frequently in the radiograph and great care and judgment must be exercised *not to misinterpret the normal antrum cavity for large filling-in abscess areas.*

Cases VI. and VII., Figures 34 and 35, present two more typical radiographs of alveolar abscess where the destruction has been great. In Case VII. we observe an involvement of the nasal cavity with a communicating sinus.

We will now consider some cases of necrosis. Case VIII., Figure 36, is particularly interesting, since it shows on the one picture the radiographic difference between abscess and necrosis. On examination the radiograph presents a large abscess cavity involving the roots of the superior right central and lateral incisors and the cuspid teeth. The upper or palatal portion *gradually shades off from dark to light,* while the lower portion shows a distinct line of demarkation. The upper portion is necrotic! This constitutes the difference. Where there is an accompanying death of tissue the process becomes thoroughly infiltrated with pus, and a condition that might be termed rarefying ostitis obtains. The gradation of shadow between the healthy and the necrotic bone structure becomes less and less apparent. We may say that wherever we observe *dark areas gradually shading into lighter ones* THE CONDITION IS CHARACTERISTIC OF NECROSIS. Note also in Figure 36 that the apex of the central root is absorbed.

Cases IX. to XIV., inclusive (Figures 37 to 42, inclusive), are all typical necrosis cases. They should be well studied and compared with the series on alveolar abscess just preceding. Figure 41 (Case XIII.) shows a necrotic condition of the maxillary suture.

Case XV., Figure 43, presents an interesting study of maxillary sinusitis. Almost the entire antrum is shown in this radiograph. The fistula connecting the antrum with the old abscess cavity that is still active in the center is well shown, as well as the extensive necrosis inside the antrum, and of the process.

One of the foremost uses of the radiograph to the dental surgeon is its application to the study of root canal fillings. It would surprise the average dentist to see the result of a hundred radiographs of root fillings made by some of the best

men in the country. In many cases, where the operator believes that he has reached the apex, a radiographic view of his work would prove to him that this is not the case. The author firmly believes the time is coming, and perhaps not so far distant, that every reputable dentist will ascertain by this absolutely sure method of investigation the result of each root filling he makes. Let us examine a few cases taken at random from the author's collection. Some of these were from cases made by students of the clinic, while others were from established practitioners. The reader may judge for himself which cases belonged to the former and which to the latter.

Case XVI., Figure 44, represents the perfect filling of an inferior second bicuspid. This filling, moreover, is *a gold filling,* and extends, as you will see, clear down to the very apex of the root. Unfortunately we do not meet with many cases where this result is obtained.

Let us contrast the last case with Case XVII., Figure 45. Here we see that the operator has succeeded in reaching the apex of the lateral root, and has even gone beyond. The result of this overzealousness is observed when we examine the rarefying ostitis surrounding the root. Also note the extent of the cuspid filling. In the first bicuspid we see a curved apex and a faint white, narrow line extending nearly to the apical foramen. This is the remains of a broach which had been left there during the extraction of the pulp, and the filling material placed in the canal on top of it.

Case XVIII., Figure 46, represents a case where a piece of an instrument has been left in the canal of a superior right central incisor. Furthermore, in the effort to remove this foreign body from the canal, the side of the canal has been perforated and an active abscess developed as seen in the picture between the central and lateral incisors. The perforation is not discernible in the radiograph, since it is in a plane at right angles to the direction of the rays.

Case XIX., Figure 47, shows how a perforation may be found by the radiograph. A wire is passed up into the canal

and the exposure made while it is temporarily held in place with a gutta-percha seal. The abscess resulting in this case is well shown.

Case XX., Figure 48, shows where two wires are sealed in the root canal for the ascertaining of a perforation, and to see if the apex of the canal has been reached.

Case XXI., Figure 49, is another example of perforated root canal, with a large quantity of filling material pushed through into the process. The result is apparent.

The shadows cast by filling materials vary but little in their relative gradations. Oxychloride, gutta-percha and cement have about the same density when used as root-filling material. Gold and amalgam cast slightly whiter shadows. 'Mummifying Paste' has about the same density as the tooth structure itself, consequently *a canal so filled appears as a root without a canal.*

Case XXII., Figure 50, shows the radiographic appearance of normal unerupted teeth in the mouth of a child. Note that in the unerupted teeth the roots have not yet developed.

Case XXIII., Figure 51, represents the impaction of two molars, crown to crown, against each other.

Case XXIV., Figure 52, shows a central incisor erupting at right angles to its normal axis.

Cases XXV. and XXVI., Figures 53 and 54, show a superior first and second bicuspid, respectively, erupting upward. This is rather an unusual position for impacted bicuspids.

Case XXVII., Figure 55, is a very rare type of inferior first molar impaction. Note as well that the third molar which can just be seen at the extreme left of the radiograph is also impacted against the second molar.

Cases XXVIII. and XXIX., Figures 56 and 57, illustrate another class of cases where the X Ray is of the greatest use to the dentist. This is where there are old roots left in the alveolus after extraction, and remain there, often unsuspected by the patient for years, till, at length, through the absorption of the process, their ragged edge digs into the gum tissue and

causes great discomfort. Their extraction is often very difficult without the aid of a radiograph, and is accompanied by the injuring of an unnecessarily large amount of gum tissue in the effort to locate them after the gum has healed over.

The foregoing twenty-nine cases are but examples of many that might be cited to demonstrate the usefulness of the ray to the up-to-date dentist. But it was not the intention of the author to reproduce these radiographs for that purpose, but rather to serve as a type of the more important classes of cases, and to show the student of the subject how to go about their proper translation, to the end that they may become used to the reading of these X Ray shadows and so make more accurate diagnoses of conditions. We might go on illustrating cases, *ad libitum,* where new and interesting conditions present, but the author prefers in this volume to limit these cases to the ones already shown, rather than to flounder in an unending sea of radiographs, the explanation of which could not possibly be contained in this present text book. At some future time, however, the author hopes to present to his readers another volume dealing more specifically with individual cases.

Figure 58 represents a radiograph of the head taken on a glass plate. Note particularly how well the inferior dental canal and foramen are shown. This picture was made by the author with an exposure of twenty seconds, at a distance from anode to plate of twenty-eight inches (the maximum distance that would be used), while testing the new standard dental outfit manufactured by the American X Ray Equipment Co. of New York.

NOTES

CHAPTER XIX.

Stereoscopic Radiographs of the Teeth

Stereoscopic radiographs of the teeth and adjacent tissues were first made and shown by the author in 1905. Since that date little has been done with them owing to the difficult technique involved.

There are many cases where it is very desirable to separate the superimposed planes of the ordinary radiograph. For example, suppose we have a picture showing two roots directly superimposed on each other, a very frequent occurrence, and let us further suppose that an abscess area is shown pointing upward from the apices of the roots. The natural question that arises is, from which root does the abscess originate? It is impossible to positively determine this from the flat single picture, but if we make stereoscopic radiographs of the condition and view them through a stereoscope the teeth stand out and take on the rotundity that they would have if actually viewed by the eyes in the dissected jaw. In other words, we would appreciate the several planes separately, and objects would appear to have all three dimensions. The original stereoscopic radiographs made by the author eight years ago were printed positives and viewed with the ordinary photographic stereoscope. The difficulty in the technique of making these pictures was twofold. First it was essential to take two radiographs of the teeth to be examined, from two viewpoints separated the normal distance that we have between the pupils of the eyes. To do this we had to move the X Ray tube just two and a half inches (the average pupilary distance) in a lateral plane between the exposures, at the same time preserving the same relative position with regard to all other planes. Secondly, we had to remove the first film from the mouth and substitute the second for the dual exposure, the second film having to be

placed in exactly the same position with regard to the tissues as the first.

The author has recently perfected a comparatively simple technique for the overcoming of these heretofore difficult features. A small plumb-bob is suspended from one of the terminals of the tube shield and this is allowed to hang freely directly over a yardstick that is mounted in a horizontal plane coinciding with the plane in which the tube must be moved during the exposure. The first picture is taken, and the tube shield moved along till the plumb-bob has traversed just two and a half inches on the yardstick and the second exposure made. To insure the placing of the second film in the absolutely same position as the first, an impression of the part of the superior arch that we wish to radiograph is first made with wax on a 'bite-plate,' and while the wax is still soft the film packet is pressed into the impression in the proper position until it leaves an indentation. The film packet is then removed, the wax chilled, and the film packet replaced. The whole impression with the film is then replaced in the mouth, the patient getting the same bite and the first exposure made. The second exposure is made in the same way, the second film packet being placed in the same indentation in the wax. This same procedure can be carried out with the lower arch by the use of a partial impression tray with the outer wall cut away. These bite plates and impression trays may be obtained from the S. S. White Co. of Philadelphia.

This method of holding the film in the mouth may be used as well for ordinary radiographs in cases where there is difficulty in the patient holding it.

The author has also recently improved the old method of viewing the stereoscopic radiographs. Formerly it was necessary to print and mount the stereoscopic pictures before they could be placed in the stereoscope, but now the negatives are used themselves. They are placed in an instrument that the author has termed a dental 'Radioscope.' This is illustrated in Figures 59 and 60.

Figure 59 represents an actual photographic view of the instrument, while Figure 60 shows the interior construction being a top view with the cover removed. A light tight viewing box is constructed with two mirrors, C and D, mounted at right angles to each other. The two stereoscopic films are mounted in the regular dental celluloid mounts and are respectively inserted in slots and grooves at either side of the mirrors, as A and B. The films, when so inserted, coming directly in front of two windows, F and G. The film on the right is capable of fine adjustment by the set screw K for lateral movement, and another set screw on the cover of the box (shown in Figure 59), which presses against the spring L for vertical adjustment. The lamps, H, at either end of the box are lighted, and the observer looks through the hood E. The right eye sees the reflection of the right negative in the mirror, D, through the lens, Y, while the left eye sees the other negative in the mirror, C, through the lens, X. The negatives are equally illuminated by the lamps, and if we manipulate the fine adjustment screws till the images of the two radiographs *register perfectly,* we will perceive a perfect stereoscopic aspect of the combined negatives. The hood, E, can be moved in or out till the focus of the lenses are adjusted to suit the eyes of the observer.

Radiographs taken and viewed in this manner show far more detail than the ordinary negatives, and in obscure cases should always be resorted to if the operator wishes to give his patient the benefit of the best means of diagnosis obtainable.

In developing these pictures care should be taken to develop them an equal length of time so that they will have the same relative density. The same is true for the original exposure.

While this book is going to press, the author is working on a new method by which he has succeeded in doing away with the double exposure altogether. When this method, which the author has termed "the radioscopic method of examination," is perfected it should so simplify the making of these pictures that they may be employed in every routine case.

NOTES

CHAPTER XX.

Conclusion

In the preceding chapters the author has tried to bring before his readers the entire subject of Dental Radiology in as clear and at the same time comprehensive a manner as possible through the medium of text and illustrations. There are many points, however, that are hard to explain by these means. Particularly is this true in regard to the coloration of the X Ray tubes. It will be only with experience that the operator can gain the ultimate success for which he is working. At the same time the cloak of mystery that has for so long enshrouded the X Ray and all pertaining to it has been steadily shrinking, till we can at last say that it is a working science. The author has endeavored to give, throughout the book, the benefit of all 'short cuts' and discoveries that he has worked out in a practice of over twelve years, particularly devoted to the study of the dental aspect of Radiology.

Students of this subject should pay particular attention to the precautions that should be taken to make its practice both safe and harmless. It is a wonderful agent that has been placed at our disposal, but it should not be abused. It has its limitations like every other branch of science, but properly *and safely* used it can do a great deal of good to suffering humanity.

Before closing it would seem desirable to give to the student starting out in the practice of Dental Radiology a few hints and suggestions as to *what not to do.*

DON'T EXPOSE YOURSELF UNDER ANY CONSIDERATION TO THE X RAYS.

DON'T ALLOW YOUR PATIENT TO SIT IN THE PATH OF THE RAYS WHILE YOU ARE TESTING TUBES.

DON'T KEEP YOUR PATIENT IN AN UNCOMFORTABLE POSITION WHILE YOU ARE ADJUSTING YOUR TUBE.

DON'T BE TOO SURE OF THE RESULT OF THE PICTURE.

DON'T MAKE TOO BIG CLAIMS FOR YOUR KNOWLEDGE OF RADIOGRAPHIC DIAGNOSIS.

DON'T HOLD FILMS IN THE MOUTH YOURSELF.

DON'T TRY TO COVER TOO LARGE AN AREA WITH ONE FILM.

DON'T USE PLATES IF YOU CAN GET THE AREA ON A FILM IN THE MOUTH.

DON'T USE OLD FILMS OR DEVELOPER.

DON'T LEAVE YOUR FILMS WRAPPED TOO LONG IN RUBBER.

DON'T FAIL TO PRESERVE A COPY OF YOUR NEGATIVE.

DON'T FAIL TO NUMBER AND FILE ALL THESE COPIES.

DON'T ABUSE YOUR TUBE; LET IT REST OCCASIONALLY FOR A WEEK AT A TIME.

DON'T ATTEMPT TO TAKE PICTURES OF OTHER PARTS OF THE BODY FOR PATIENTS UNLESS YOU HAVE HAD INSTRUCTION.

DON'T TRY TO DRY YOUR NEGATIVES BY HEAT OR IN THE SUN.

DON'T TAKE A RADIOGRAPH OF A PATIENT UNLESS THERE IS A WITNESS IN THE ROOM.

DON'T TAKE RADIOGRAPHS OF PATIENTS FOR RIDICULOUSLY LOW FEES. BETTER TAKE IT FOR NOTHING THAN TO UNDERESTIMATE YOUR SERVICES.

DON'T CHARGE PROHIBITIVE FEES, EITHER.

DON'T FAIL TO THOROUGHLY UNDERSTAND THE WORKING OF YOUR APPARATUS.

DON'T STORE YOUR FILMS AND PLATES WHERE THEY MAY POSSIBLY RECEIVE X RAY EXPOSURE.

DON'T FAIL TO SWAB OFF YOUR NEGATIVES AFTER WASHING WITH ABSORBENT COTTON.

DON'T ALLOW ANYONE TO GET NEAR THE CONDUCTING WIRES WHILE THE APPARATUS IS WORKING.

DON'T HANDLE A WET NEGATIVE ANY MORE THAN NECESSARY.

DON'T FAIL TO TAKE A RADIOGRAPH IN EVERY CASE WHERE YOU THINK IT WILL BE OF BENEFIT TO YOU OR YOUR PATIENT.

THE END.

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